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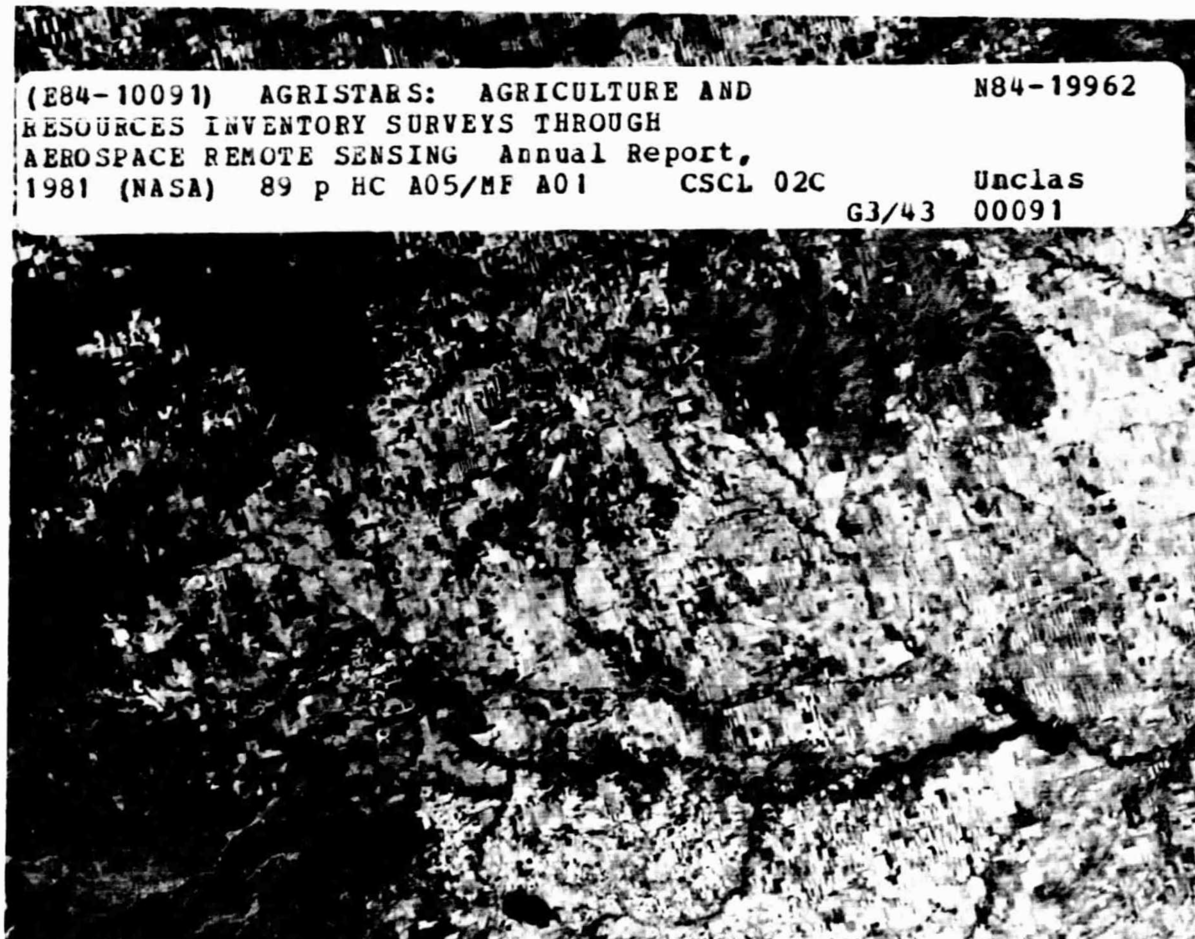

A Joint Program for Agriculture and Resources Inventory Surveys Through Aerospace Remote Sensing

AP-J2-04225

AgRISTARS

AGRICULTURE AND RESOURCES INVENTORY SURVEYS THROUGH AEROSPACE REMOTE SENSING

ANNUAL REPORT - FISCAL YEAR 1981

Prepared by

AgRISTARS Program Support Staff

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
LYNDON B. JOHNSON SPACE CENTER
HOUSTON, TEXAS 77058

January 1982

PREFACE

The AgRISTARS program was initiated in fiscal year 1980 in response to an initiative issued by the U.S. Department of Agriculture. Led by the USDA, the program is a cooperative effort with the National Aeronautics and Space Administration, the National Oceanic and Atmospheric Administration of the U.S. Department of Commerce, the U.S. Department of the Interior, and the Agency for International Development of the U.S. Department of State.

The program goal is to determine the usefulness, cost, and extent to which aerospace remote sensing data can be integrated into existing or future USDA systems to improve the objectivity, reliability, timeliness, and adequacy of information required to carry out USDA missions.

The program is well underway, with encouraging progress having been made in fiscal years 1980* and 1981. The outlook is that aerospace remote sensing will contribute to USDA information needs in a significant way and, more generally, that the AgRISTARS effort will advance this technology for use in other areas of national need.

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*AgRISTARS Annual Report - Fiscal Year 1980; AP-J0-04111, National Aeronautics and Space Administration, Lyndon B. Johnson Space Center, June 1981.

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FIGURES

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ACRONYMS

AgRISTARS	Agriculture and Resources Inventory Surveys Through Aerospace Remote Sensing
agromet	agricultural-meteorological
AID	Agency for International Development
APEP	Advanced Proportion Estimation Procedure
ARS	Agricultural Research Service
ASMA	Automatic Segment-to-Map Algorithm
CCT	computer-compatible tape
CEAS	Center for Environmental Assessment Services
CFS	continuous flow simulation
CMI	crop moisture index
C/P	Conservation and Pollution
CPU	computer processing unit
CWSI	crop water-stress index
DC/LC	Domestic Crops and Land Cover
EDIS	Environmental Data and Information Service
ERL	Earth Resources Laboratory
ESP	extended streamflow prediction
EVI	environmental vegetative index
EW/CCA	Early Warning and Crop Condition Assessment
FAS	Foreign Agricultural Service
FCPF	Foreign Commodity Production Forecasting
FY	fiscal year
GAC	global area coverage
GOES	Geostationary Operational Environmental Satellite
GSFC	Goddard Space Flight Center
GSS	Ground Scatterometer System
ICC	Interagency Coordinating Committee
IPB	Interagency Policy Board
ISOCLS	Iterative Self-Organizing Clustering System
ITD	Inventory Technology Development
JES	June Enumerative Survey

JPL	Jet Propulsion Laboratory
JSC	Lyndon B. Johnson Space Center
LAC	local area coverage
LACIE	Large Area Crop Inventory Experiment
metsat	meteorological satellite
MSS	multispectral scanner
MUSSL	Marine Unwelled Spectral Signature Laboratory
NASA	National Aeronautics and Space Administration
NCC	National Climatic Center
NESS	National Environmental Satellite Service
NMR	nuclear magnetic resonance
NOAA	National Oceanic and Atmospheric Administration
NSTL	National Space Technology Laboratories
NWSRFS	National Weather Service River Forecast System
pixel	picture element
PMT	Project Management Team
ppm	parts per million
PSS	Program Support Staff
RMSE	root mean square error
RRI	Renewable Resources Inventory
SAR	synthetic aperture radar
SAS	Statistical Analysis System
SCS	Soil Conservation Service
SM	Soil Moisture
SR	Supporting Research
SRS	Statistical Reporting Service
TM	thematic mapper
USDA	U.S. Department of Agriculture
USDC	U.S. Department of Commerce
USDI	U.S. Department of the Interior
VICAR	Video Image Communication and Retrieval
YMD	Yield Model Development

I. PURPOSE

The purpose of this report is to present the major objectives and accomplishments of the Agriculture and Resources Inventory Surveys Through Aerospace Remote Sensing (AgRISTARS) program and its eight component projects during fiscal year (FY) 1981.

The report includes an introduction to the overall AgRISTARS program, a general statement on progress, and separate summaries of the activities of each project. The primary emphasis is on the technical highlights. It is planned to issue similar annual reports around January of each year. Organizational and management information on AgRISTARS is included in the appendixes, as is a complete bibliography of publications and reports. Additional information may be obtained from:

AgRISTARS Program Support Staff,
Code SK
NASA Lyndon B. Johnson Space
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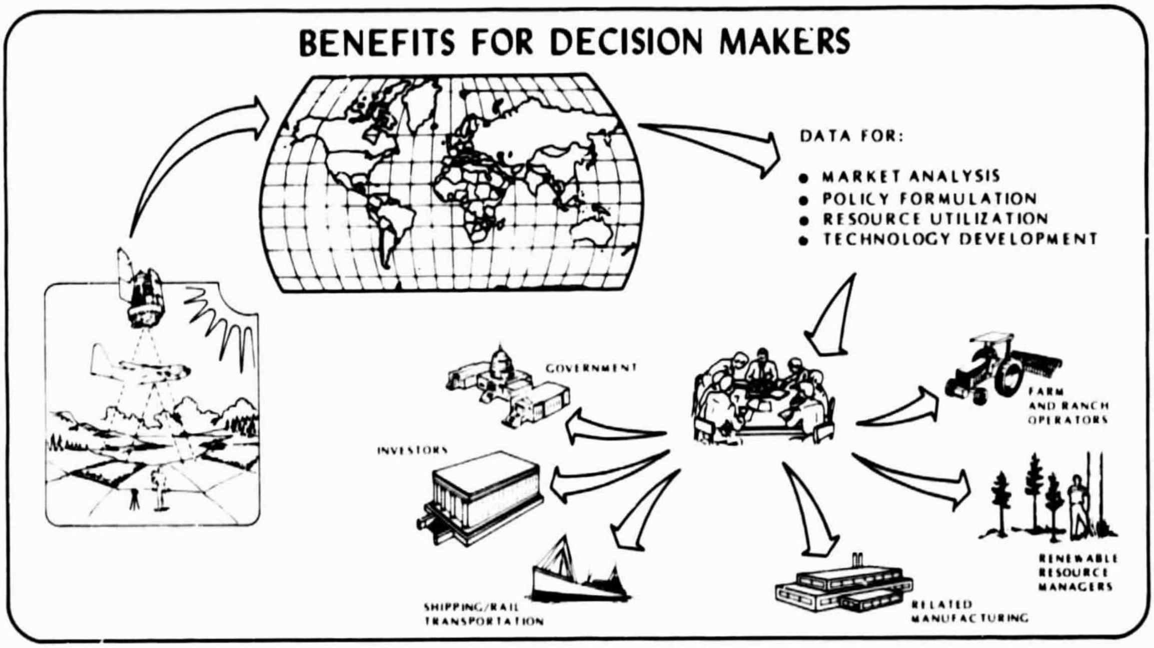
2. INTRODUCTION

AgRISTARS is a long-term program of research, development, test, and evaluation of aerospace remote sensing to meet the needs of the U.S. Department of Agriculture (USDA). The program is a cooperative effort of: the USDA; the National Aeronautics and Space Administration (NASA); the U.S. Department of Commerce (USDC) through its agency, the National Oceanic and Atmospheric Administration (NOAA); and the U.S. Department of the Interior (USDI). In addition, the Agency for International Development (AID) of the U.S. Department of State participates as an ex-officio observer and potential future user agency.

In 1978, the Secretary of Agriculture issued an initiative,[1] in response to which the participating agencies established the AgRISTARS program. In 1980, the program was initiated as an effort based on satisfying current and future requirements of the USDA for high-priority agricultural and other renewable resources type information. This information is important to the USDA in addressing national and international issues on supply, demand, and competition for food and fiber.

The overall goal of AgRISTARS is to determine the feasibility of integrating aerospace remote sensing technology into existing or future USDA data acquisition systems. Determining feasibility depends upon the assessment of numerous factors over an extended period of time. Determinations of the reliability, costs, timeliness, objectivity, and adequacy of information required to carry out USDA missions are planned in the program. The overall approach consists of a balanced program of remote sensing research, development, and testing which addresses a wide range of information

[1] Joint Program of Research and Development of Uses of Aerospace Technology for Agricultural Programs, February 1978.



Remote sensing technology is being developed to give timely, reliable information to those concerned with the worldwide status of renewable resources.

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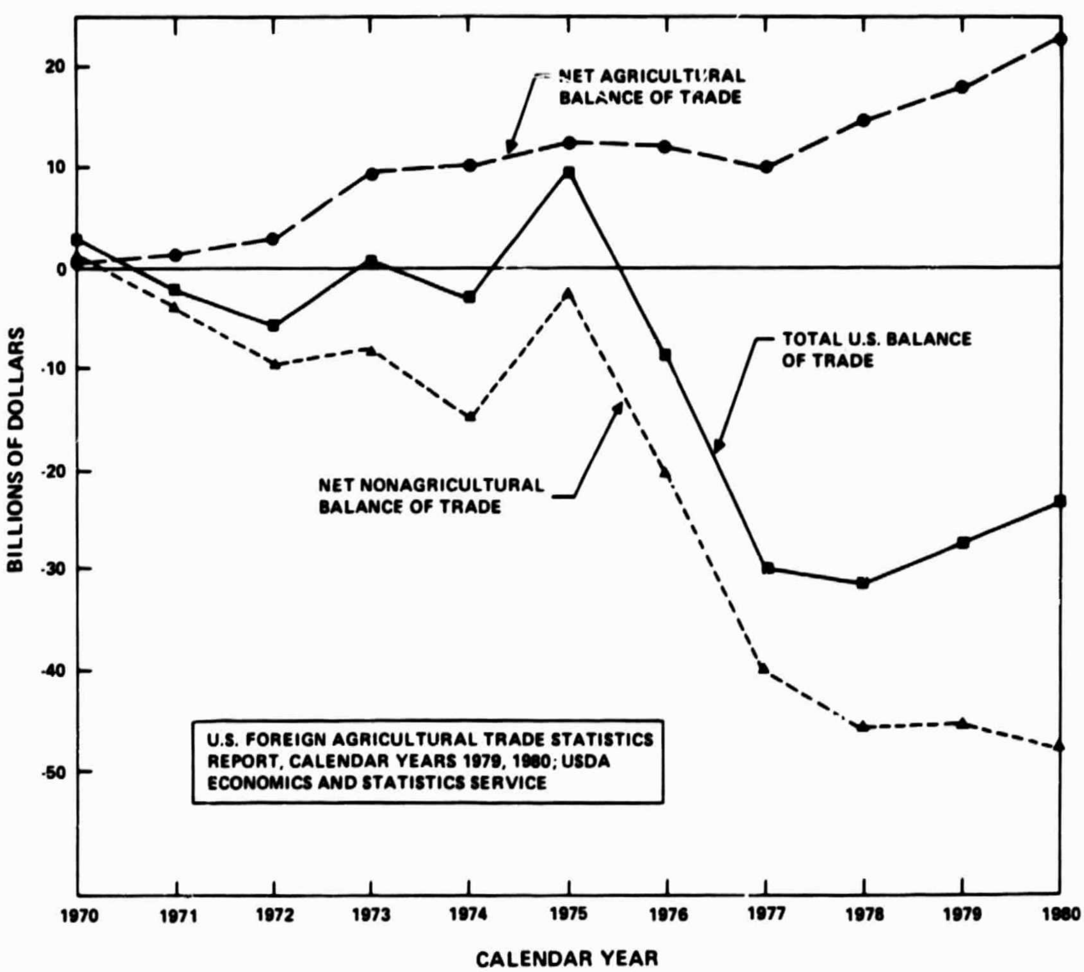
needs on domestic and global resources and agricultural commodities.

In this initiative, the USDA identified the following seven information requirements:

- Early warning of change affecting production and quality of commodities and renewable resources
- Commodity production forecasts
- Land use classification and measurement
- Renewable resources inventory and assessment
- Land productivity estimates
- Conservation practices assessment
- Pollution detection and impact evaluations

U.S. AGRICULTURE'S CONTRIBUTION TO BALANCE OF TRADE



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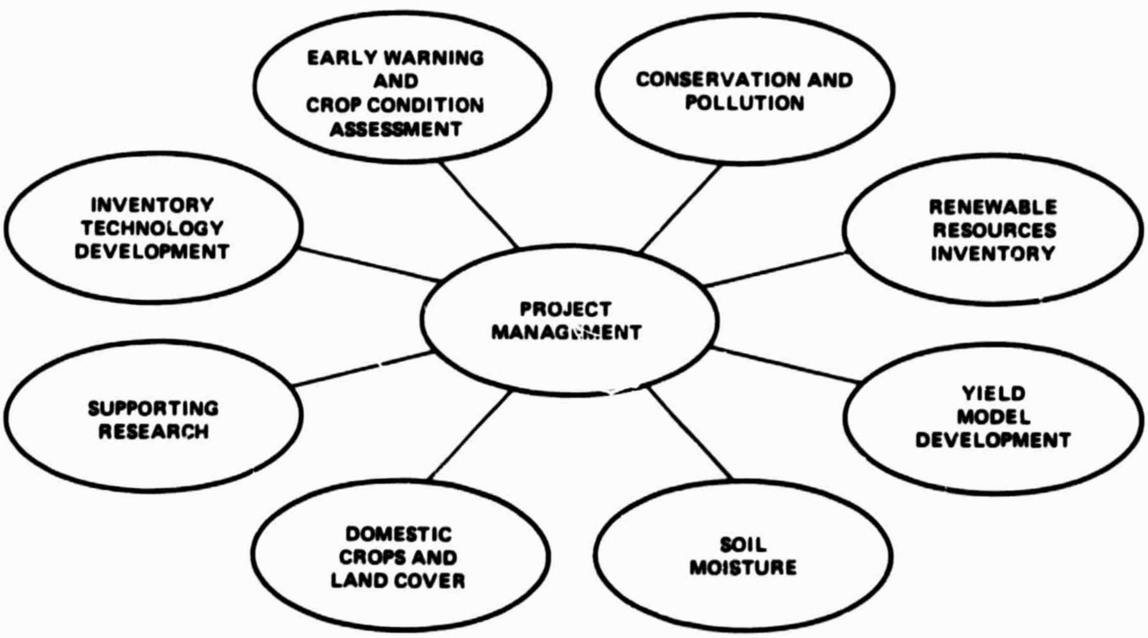
Based on these information requirements, as well as on a specific immediate need for better or more timely information on crop conditions and expected production, the AgRISTARS technical program was developed. It consists of eight projects which address all seven of the USDA information needs with a clear emphasis on the first two, early warning of change and commodity production forecasts. The eight projects include the following:

- Early Warning and Crop Condition Assessment (EW/CCA)
- Inventory Technology Development (ITD)[2]
- Yield Model Development (YMD)
- Supporting Research (SR)
- Soil Moisture (SM)
- Domestic Crops and Land Cover (DC/LC)
- Renewable Resources Inventory (RRI)
- Conservation and Pollution (C/P)

Each project has its specific set of objectives and is treated in this report as a discrete element of the AgRISTARS program. The projects are interrelated both through mutuality of information needs and through much common technology. The approach for all projects calls for exploratory experiments, pilot and/or large-scale applications tests, and USDA user evaluations.

[2]Formerly known as the Foreign Commodity Production Forecasting (FCPF) project.

AgRISTARS PROJECTS



3. PROGRAM SUMMARY

The AgRISTARS program is well underway with meaningful progress having been made during FY 1981, the second year of the effort. Scientists and support personnel from the participating Government agencies, from universities, and from industry are assigned to AgRISTARS research at some 35 locations in the United States. A multi-agency program management structure has been established and is functioning with planning and reporting mechanisms in place. Each of the participating agencies is supporting the program pursuant to a Memorandum of Understanding dated January 16, 1980.

The outlook for activity under the AgRISTARS program is that aerospace remote sensing technology will indeed contribute in a significant way to meeting the information needs of the USDA. Further, it is anticipated that AgRISTARS will be a major stimulus to advance remote sensing technology in general and thus will contribute to the exploitation of this technology in other areas of national need.

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4. PROJECT SUMMARIES

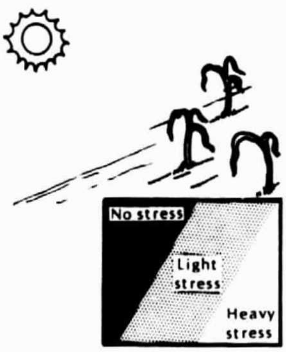
4.1 EARLY WARNING/CROP CONDITION ASSESSMENT

The EW/CCA research effort is designed to develop and test remote sensing techniques which will make possible or enhance operational methodologies for crop condition assessment. This technology will be used by elements of the USDA, in particular the Foreign Agricultural Service (FAS) of the USDA, which is responsible for providing early warning of changes which may affect foreign crop production and quality and for assessing crop conditions. The EW/CCA project is led by the USDA Agricultural Research Service (ARS) with participation by NASA and NOAA. The project activity includes techniques for alerting, monitoring, and assessing conditions that impact crop production in both foreign and U.S. areas. Major commodities for which technology is being developed include small grains (wheat and barley), corn, soybeans, sorghum, sunflowers, sugar beets, and cotton.

EARLY WARNING OF CONDITIONS AFFECTING CROPS

This project will assist the USDA in tracking the condition of major crops in the United States and foreign countries.

Techniques using data from satellites to measure the effects of drought on crops are well developed, and the areas of the crops affected can be accurately measured. Other types of crop stress are also being studied.



Major accomplishments in FY 1981 were:

- The development and testing of several crop-stress-alarm models which also provide regional soil moisture and crop calendar information.

- The development of environmental threshold values and background information for other crop-stress models.

- The development of a crop water-stress index (CWSI). This index is now ready for testing on data from aircraft and satellite platforms.

- The initiation of studies to quantify crop stress spectrally. Initial results indicate that water stress can be detected and measured spectrally before stress can be detected visually.

- The development of the capability for using environmental satellite data to monitor floods and general crop conditions over large areas.

4.2 INVENTORY TECHNOLOGY DEVELOPMENT

The objective of ITD activity is to develop and test techniques for using space remote sensing technology to provide objective, timely, and reliable forecasts of foreign crop production without requiring ground observations. The prospective users of this technology are the USDA/FAS and various international organizations concerned with world food and fiber supply. The project is led by NASA with participation by USDA and NOAA. In achieving its objective, the ITD research considers eight crop/region combinations in the United States and five foreign countries, including the U.S.S.R., Argentina, Brazil, Canada, and Australia. Small grains, corn, and soybeans will be studied. ITD research expands and improves upon the remote

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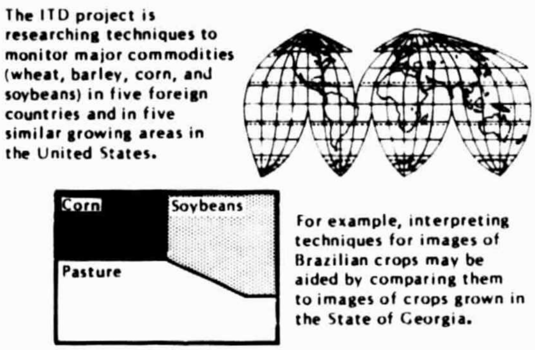
sensing technology developed in previous experiments during the mid-1970's.

INVENTORY TECHNOLOGY DEVELOPMENT



Major accomplishments in FY 1981 were:

- The first successful development and experimental testing of efficient automated methods for producing crop area estimates for spring small grains. These tests imply that data analysis costs will not be a significant cost factor in making objective crop area estimates for major crops in foreign regions using Landsat-type data.

- The further development of techniques for corn and soybean area estimation based on FY 1980 results. Initial testing shows substantial improvements in the accuracy of the estimates.

- Design and partial implementation of an area/production estimation simulator. This simulator will allow more comprehensive performance assessments of technology components.

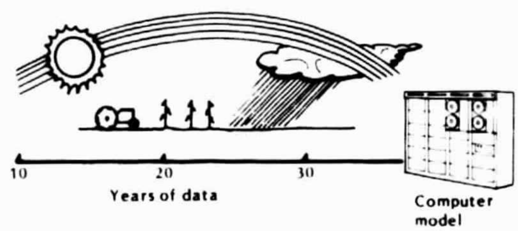
- Acquisition of a second year of extensive ground-truth data and coincidental Landsat imagery to support research and development for the crop regions of interest. This included ground observations in 133 U.S. sites and in 16 Argentina sites.

4.3 YIELD MODEL DEVELOPMENT

The YMD research effort utilizes measurements of environmental and plant characteristics to project crop yield potential within a region. This effort is a key component of any commodity production forecasting methodology and, as such, contributes to both the domestic and foreign crop estimation processes. NOAA, through the Environmental Data and Information Service, Center for Environmental Assessment Services (EDIS/CEAS), leads this activity with support from USDA and NASA.

YIELD MODEL DEVELOPMENT

This is research to determine how various crops will respond to weather conditions, agricultural practices, and other factors. Many years of data are taken into account.



Major accomplishments in FY 1981 were:

- An evaluation of available wheat, barley, corn, and soybean regression-type yield models; the selection of the most responsive model for each crop; the preparation of required yield estimates from selected models; and the delivery of recommendations and estimates to the ITD project manager.

- The development of a new methodology using meteorological satellite (metsat) data for estimating solar radiation at the surface and the validation of the accuracy of these estimates.

- The compilation of five wheat growth simulation models, the testing of two of the five, and the documentation of recommendations for improvement.

- The development of a model that relates water stress, caused by low soil moisture or high energy input levels, to photosynthesis limitation in soybeans.

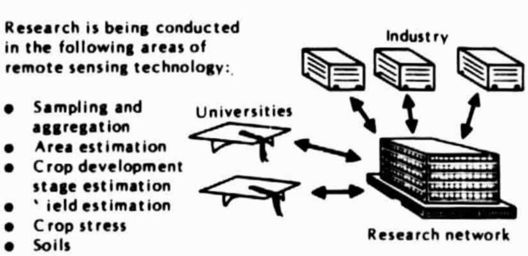
- The adaptation of the wheat simulation model to barley.

4.4 SUPPORTING RESEARCH

This project is designed to provide technological components and procedures for testing in the other AgRISTARS projects, notably in the crop inventory activities. Research focuses on techniques to extract, from Landsat data, information on the area planted to different crops; on the stage of development of wheat, barley, corn, and soybeans; and on the crop condition determined from spectral analyses of the crops. This activity is led by NASA with support from USDA and NOAA.

The crops of concern to the EW/CCA and ITD projects are being studied by the SR project. In addition, natural vegetation and soils are important subjects of study.

SUPPORTING RESEARCH



Major accomplishments in FY 1981 were:

- The development and testing of a wheat stress index model derived from a simulation of daily crop moisture stress and phenological development. Initial testing, using 1980 U.S. Great Plains data, shows a marked improvement in the accuracy of the model over previous models.

- The simulation of data which will be collected by the Landsat thematic mapper (TM), to be launched in late 1982, using both an aircraft scanner and a field spectrometer to predict performance. Results obtained from a small grains and corn area in South Dakota indicate that the TM spatial resolution of 30 meters will provide data with much less of the full boundary confusion than was the case for the multispectral scanner (MSS). Specifically, 75 percent of the picture elements (pixels) in the TM scene will lie totally within fields and thus will contain the "signature" of only one crop, compared to only 35 percent for the MSS.

- Further development of an automated crop area estimation procedure. This procedure uses multitemporal Landsat MSS data to model crop growth automatically and meteorological data to model crop planting dates and crop stages of development. Analysts manually identify a small sample of pixels for training computer classification programs. Verification tests of the procedure show accurate crop estimates, and results indicate that complete automation of the procedure may be possible in the future. In addition, test results indicate that, using this new procedure, corn area estimation is possible about 60 days after planting.

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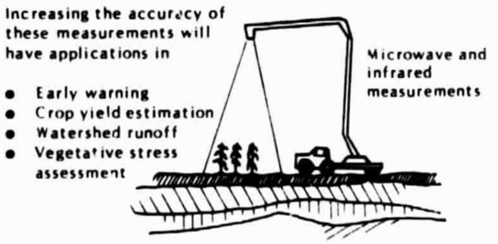
- Improvement of Landsat MSS multitemporal data registration using a newly developed registration processor. Initial testing shows an accuracy at or below 0.5 pixel, compared to an earlier capability of ±1.0 pixel. Further improvements are in work, with a goal of 0.2 pixel accuracy. This accuracy is needed in order to classify small and strip/fallow fields where successive pixels may be in and out of fields without tight registration accuracy.

4.5 SOIL MOISTURE

The objective of the SM project is to develop and evaluate the technology for the remote and ground measurements of soil moisture. This technology is an intermediate step in the application of remote sensing, in that a knowledge of soil moisture is important to models which predict items such as crop yield, plant stress, and watershed runoff. This work will provide knowledge about a key variable needed in several other AgRISTARS projects. This activity is led by the USDA Soil Conservation Service (SCS) with support from NASA. The scope of the work includes the improvement of in situ soil moisture measurement techniques and, through mathematical modeling efforts, relating these in situ measurements to remotely sensed measurements. Applications of the results will be made over broad regions to various agricultural and hydrological problems.

SOIL MOISTURE STUDIES



Major accomplishments in FY 1981 were:

- The finding of substantial agreement between theory and measurements of the penetration depth of certain microwave bands. Also, it appears that time of day may be an important consideration in the remote sensing of soil moisture.

- The commencement of work on a portable surface soil moisture measuring instrument to be used for rapid ground-truth measurements over large areas.

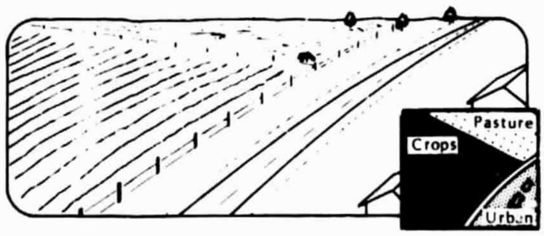
- Further quantification of the effects that vegetation has on microwave soil moisture measurements. Results show that they must be considered when making these measurements.

4.6 DOMESTIC CROPS AND LAND COVER

The DC/LC crop acreage objectives are to improve state and substate crop acreage estimates by integrating Landsat data with ground data from the existing USDA program and to evaluate the effectiveness of alternative procedures. The land cover objectives are to explore methods for meeting USDA needs for land cover inventories, land use change estimates, and mapping products of land cover.

DOMESTIC CROPS AND LAND COVER

Directed at automatic classification and estimation of land cover with emphasis on major crops, this project uses Landsat and advanced sensor data to improve accuracy of data classification on the local level.



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This project is led by the USDA Statistical Reporting Service (SRS) with support from NASA. Major crop estimates are being addressed first in the U.S. Great Plains for wheat and in the U.S. Corn Belt for corn and soybeans. Plans call for adding two states each year to the crop estimation research.

Major accomplishments in FY 1981 were:

- The completion of revised 1980 major crop acreage estimates in Iowa and Kansas before the end of the estimation season.
- The implementation of state statistical office procedures for Missouri and Oklahoma, in addition to Iowa and Kansas, for 1981.
- A comparison of USDA/SRS and NASA data registration techniques.
- The completion of a TM simulator study on crop acreage classification.
- An evaluation of several change detection procedures for one test site.
- A statewide land cover survey in Kansas conducted in conjunction with an existing survey.

4.7 RENEWABLE RESOURCES INVENTORY

The objectives of the RRI project are the development and implementation, in the USDA Forest Service, of new remote sensing technology which will offer capabilities in support of the national renewable resource assessment process. The USDA Forest Service will be the user of the technologies developed under the RRI project. The Forest Service is the lead agency in this project. The scope of the effort includes: (1) improving high-altitude aircraft sensor and pallet capability; (2) mapping and characterizing natural and managed habitation; (3) collecting, displaying, and using resource information to aid in forest management and planning; (4) demonstrating advanced capabilities for monitoring, classifying, and measuring disturbances and changes in forests and rangeland; and (5) evaluating Landsat technology as a tool for supporting multiresource inventories and forest planning.

RENEWABLE RESOURCES INVENTORY

Four main categories are being addressed:

(1) National inventory
(2) Stress/damage assessment
(3) Timberland classification
(4) Environmental/land use

Use of data from the Landsat multispectral scanner and the more detailed data from the improved sensors is planned.

Major accomplishments in FY 1981 were:

- The simulation of the Landsat-D TM using panoramic cameras. Results indicate that the accuracy of forestry type mapping will almost double and that existing software at NASA's National Space Technology Laboratories, Earth Resources Laboratory (NSTL/ERL) will process TM data successfully. Additionally, a Seasat synthetic aperture radar (SAR) study showed improved delineation of deciduous forests.
- Evaluations, using Landsat MSS data, of wildlife habitat areas derived from vegetation cover maps and of procedures for habitat type mapping.

- Further advancement of the Multi-resource Inventory Methods Pilot Test. Computer classification programs were evaluated; an implementation plan was developed for land management planning in the San Juan National Forest in Colorado; and computer systems together with remote access systems were evaluated.

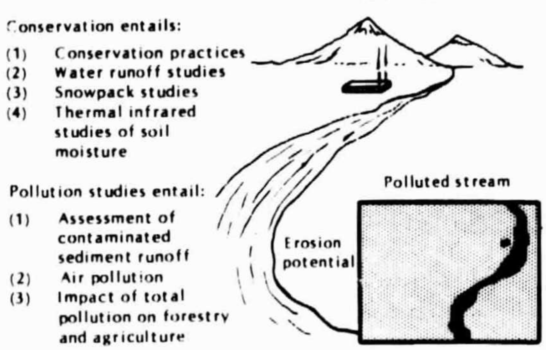
- Significant results and preliminary results have been obtained from tests of new procedures for change detection, classification, and measurement of disturbances and changes.

4.8 CONSERVATION AND POLLUTION

The conservation assessment portion of the C/P project addresses applications in three areas: inventory of conservation practices, estimation of water runoff using hydrologic models, and determination of physical characteristics of snowpacks.

The pollution portion of the C/P project will provide an assessment of conservation practices through the use of remote sensing techniques to quantitatively assess sediment runoff, to detect gaseous and particulate air pollutants, and to assess their impacts on agricultural and forestry resources.

CONSERVATION AND POLLUTION



The USDA leads this project with support from NASA and NOAA.

Major accomplishments in FY 1981 were:

- Studies of watershed runoff, which was shown to be extremely sensitive to the amount of soil moisture in the surface layers.

- The development of procedures for using Landsat images to determine SCS water runoff model curve numbers.

- Testing of a snowmelt model on U.S. river basins with good results.

- Further advancement of a model relating snow depth to microwave brightness.

- The finding that snow boundaries can be detected by 37-gigahertz or 18-gigahertz data.

- Spectral studies of suspended sediments in reservoirs. Results indicate that TM band 4 will be useful for mapping suspended sediments.

- Measurements of spectral differences in plants exposed to 0.6 parts per million (ppm) ozone for 2 hours.

5. PROJECT TECHNICAL HIGHLIGHTS

In each of the AgRISTARS projects, there has been good progress across a broad front, and the results have been documented in detail (see appendix B). The purpose of this section is to focus on the most significant accomplishments in each project. If the reader desires greater detail, he should consult the key references noted below each of the highlighted efforts.

5.1 EARLY WARNING/CROP CONDITION ASSESSMENT

5.1.1 Technical Objectives

The central objective of the research and development activity is to provide a capability for the USDA to assess and respond in a timely manner to factors affecting the quality and production of economically important crops. Primary program technical objectives are:

- To develop, test, and evaluate the use of meteorological and satellite data with various simulation models and known environmental thresholds to provide timely alerts of abnormal and optimal conditions on a global basis.
- To develop, test, and evaluate alternative uses of NOAA-6 and NOAA-7 satellite data to monitor and alert for abnormal conditions.
- To provide improved definition of the relationships between plants and their environment and factors affecting the normal growth cycle.
- To determine relationships between crop stress and spectral response.
- To develop a gridded U.S. data base for year-to-year change analysis.

5.1.2 Alarm Models

Model development and/or improvements were made to provide alarms for potentially damaging ambient conditions including water and temperature stresses for wheat, corn, sorghum, and soybeans. The wheat, corn, and sorghum models have been transferred to the USDA/FAS data base for synoptic applications. A sorghum stress model (fig. 1.) illustrates both optimum and hazardous moisture and temperature conditions that may occur at various plant growth stages. Additional outputs are preseason stored soil moisture status and tractability problems at the planting and harvest periods. To support the alarm model development, an improved soil water budget model and location-specific crop calendar models for each crop were developed and implemented in conjunction with an existing USDA data base. Because phenology determines plant stress response, adequate crop calendar information is essential.

Modeling efforts have also been directed toward the prediction of disease epidemics, particularly rusts, of small grain cereals. Major pathogens have been identified along with inoculum sources for all major agricultural areas of the world. Meteorological constraints during the different critical phases of disease cycling were defined for several pathogens, with major emphasis on stripe rust. Initial spectral data indicate the feasibility of impact analysis following areal discrimination based on a meteorologically driven algorithm.

5.1.3 Condition Assessments

Soil water, when in limited supply or in excess, is a major factor in crop condition and production. The EW/CCA project is involved in several tasks to detect, monitor, and determine the degree of water stress for several crops. The tasks range in scope from basic crop response research, to applied research at the farmer level, to applications based on satellite (Landsat and meteorological) observations. One significant contribution has been the development of the CWSI. This index based on the difference between plant canopy and ambient air temperature and vapor pressure deficit appears to track water stress for cotton, wheat, and alfalfa. The index was developed and tested using plot data. Its use is being extended to aircraft data this year, and plans are in preparation to

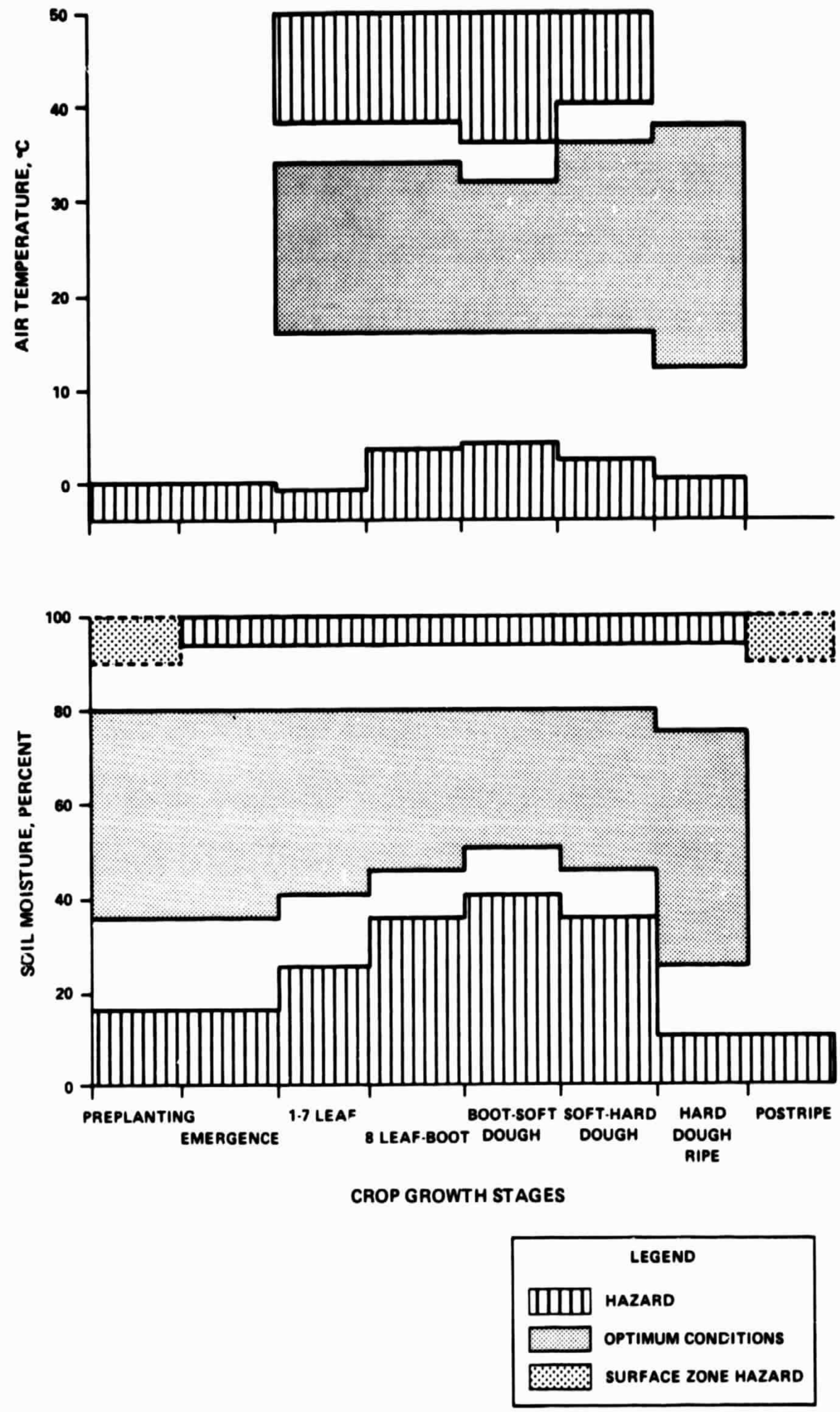


Figure 1.- A sorghum model providing daily hazardous and/or optimum flags for moisture and temperature conditions at various crop phenology stages.

determine the value of the index for large areas using Geostationary Operational Environmental Satellite (GOES) data. The CWSI appears to have broad geographic applications for several crops. When the index is large during fruiting of cotton, a definite response is seen in yield (fig. 2). This index is an excellent example of complementary use of remote and in situ observations since, for large-area applications, canopy temperature will be determined remotely.

Field plots were established in Bushland, Texas, to measure crop water stress and spectral response from four crops. The spectral data were obtained using ground-based radiometers. Initial results indicate that water stress in corn can be detected and measured remotely before stress can be detected visually. An initial atmospheric correction model has been developed so that ground-based radiometer data can be interpreted relative to space platform data.

The feasibility of monitoring rangelands to assess water stress in adjacent croplands is being studied. Initial findings suggest a potential for using rangelands as a soil moisture crop stress indicator; however, Landsat acquisitions may be too infrequent to provide reliable data. Future research may demonstrate the utility of NOAA-6 and NOAA-7 satellite data.

Plant stress caused by flooding also results in significant crop damage. Thus, a classifier and estimator of flooded area were developed. The classifier and estimator (fig. 3) are components of a flood assessment model used to monitor flood damage.

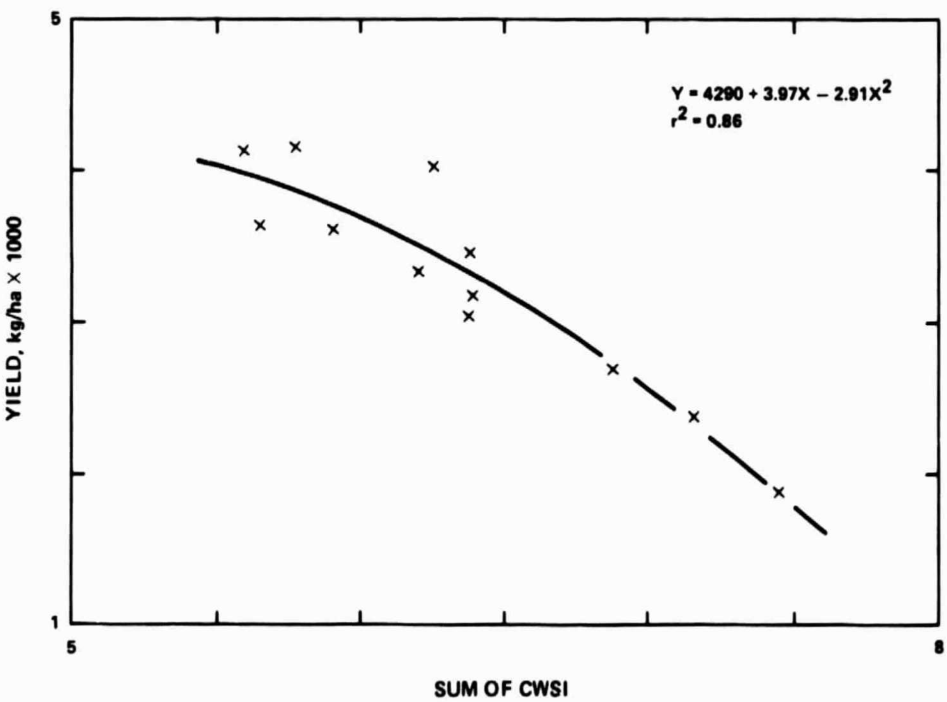


Figure 2.- Cotton yield versus sum of CWSI during fruiting.

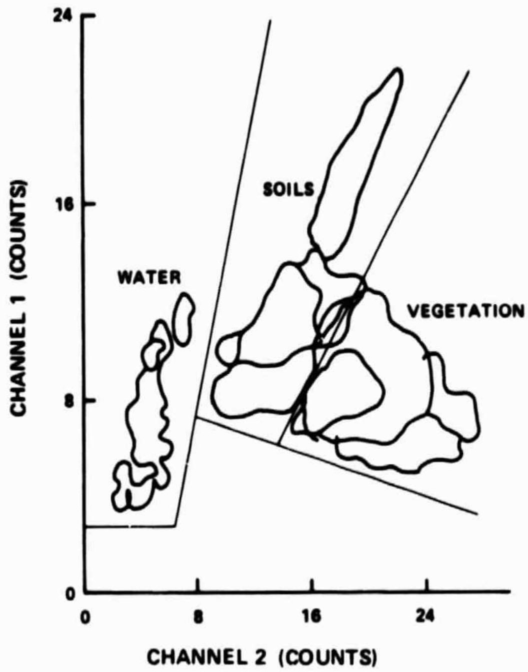


Figure 3.- Flood project classifier for delineation of water, vegetation, and soils using NOAA-6 spectral data.

The EW/CCA project is utilizing an established geographical grid to define the boundaries for a U.S. data base. The grid cell represents an area of approximately 25 by 25 miles. The data base contains geographic and physiographic data for each cell. These data include political entities, land resource areas, major soil types, and major crops with associated crop calendars. Each cell is referenced to meteorological and satellite data. The meteorological data include daily precipitation, maximum and minimum temperatures, evapotranspiration, snow cover, and solar radiation. These data are received within 10 days of occurrence and reside in the data base for at least 90 days. NOAA satellite data are received within 48 hours after acquisition, and computed vegetative index numbers reside in the data base for at least 1 year. When the data base is purged, the data are stored on tapes for research purposes. Landsat data are also available for certain specific grid cells. Current computer capability will accommodate 1200 grids in the central part of the United States.

5.1.4 Environmental Satellites

Information from the NOAA-6 and NOAA-7 environmental satellites was analyzed to determine relationships between vegetation characteristics and satellite-derived indices of greenness. Correlation analysis indicates a good relationship between Landsat and NOAA-6 data (fig. 4). Single-channel

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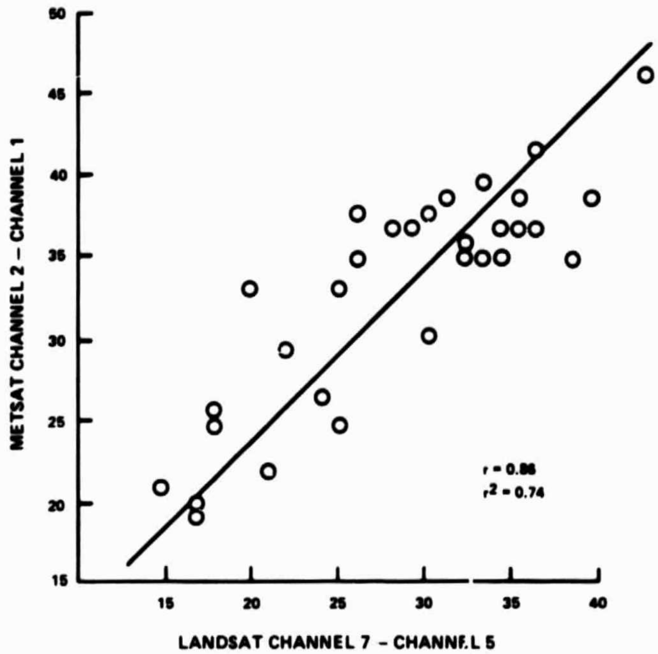


Figure 4.- Relationships between Landsat and environmental satellite data.

data and/or vegetative index numbers have been used in drought studies, flood monitoring and assessments, and general crop condition studies. Other studies involve illumination effects, viewing angle effects over nonuniform surfaces, and information content of geographic grids and/or global area coverage (GAC) and local area coverage (LAC) pixels.

Figure 5 illustrates the temporal change in overall greenness of two geographic grids during the summer of 1981. Changes in greenness correspond quite well to amounts of precipitation recorded at nearby weather stations. A data base including the NOAA-6 and NOAA-7 data will be evaluated in 1982 for year-to-year changes. The EW/CCA project supported the development of a two-channel metsat processor for USDA/FAS. Modifications for the processor are provided as improved coefficients and cloud-screening algorithms are developed.

A regional aridity index using environmental satellite data was developed. This index is based on satellite-derived surface temperature relative to weather station air temperature. Areas of least freeze hazard were also delineated usin nighttime satellite data.

Estimates of precipitation over Brazil (January 1981) and the U.S.S.R. (May through August 1981) derived from polar-orbiting satellites were prepared for AgRISTARS evaluation.

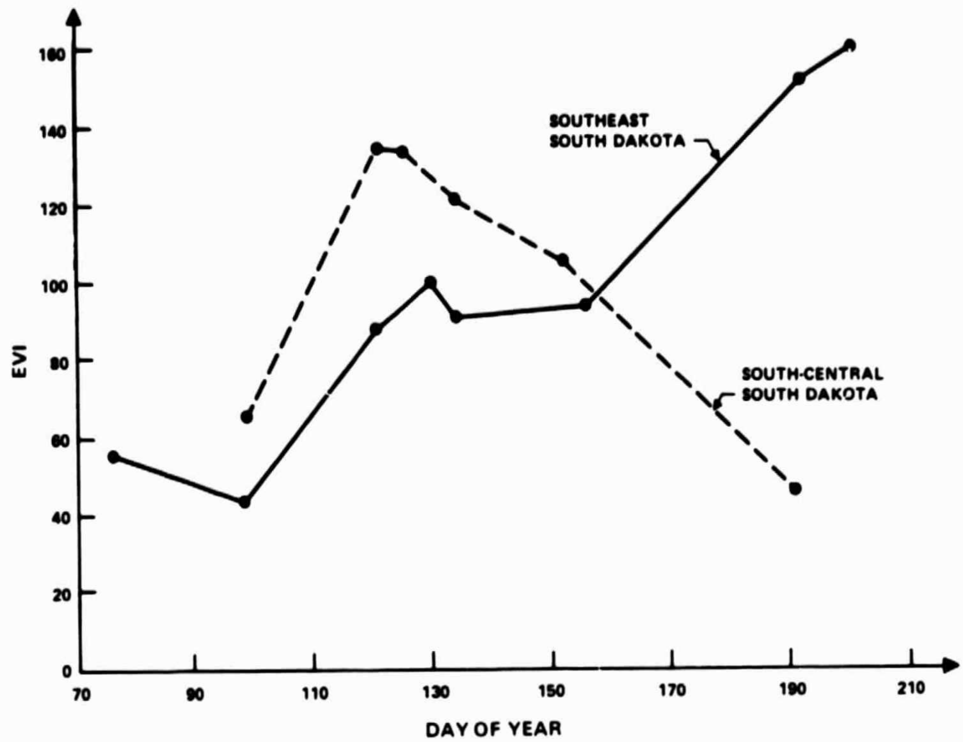


Figure 5.- Environmental satellite vegetative index (EVI) trajectories computed for i,j grids in southeast and south-central South Dakota.

5.2 INVENTORY TECHNOLOGY DEVELOPMENT

5.2.1 Technical Objectives

The general objective of the ITD project is to research methods for making improved crop production forecasts in foreign areas without requiring ground observations. The focus of this work in FY 1981 was on:

- o Automating and improving the efficiency of reliable spring small grains crop identification/area estimation technology, as well as conducting evaluations on a multiyear (1976-79) data set.
- o Developing a reliable corn and soybean area estimation technique based on the crop identification procedures developed in 1980 and initiating a test of this technology while simultaneously developing more efficient automated alternative techniques.
- o Constructing components of an integrated simulator of a conceptual crop area/production forecasting system that will permit more comprehensive performance evaluations of alternative foreign crop estimation technology components.
- o Acquiring a second year of extensive ground-truth and correlated Landsat data to support subsequent research and development efforts.

5.2.2 Estimation of Crop Areas — Spring Small Grains

Previous research in the detection of spring small grains with highly objective analysis procedures led to the development and evaluation of an almost totally automated technology.

This evolved from the fact that progress had been made in improving accuracy of the spring small grains estimates, which allowed emphasis to be placed on making the techniques more objective and efficient.

With this emphasis, the ITD project developed three almost totally automated spring small grains techniques that were evaluated over a multiyear (1976-79) data set of varying climatic conditions (fig. 6). These data include ground-truth data and coincidental remotely sensed Landsat imagery covering approximately 5000 square miles in four U.S. northern Great Plains states and Saskatchewan, Canada.

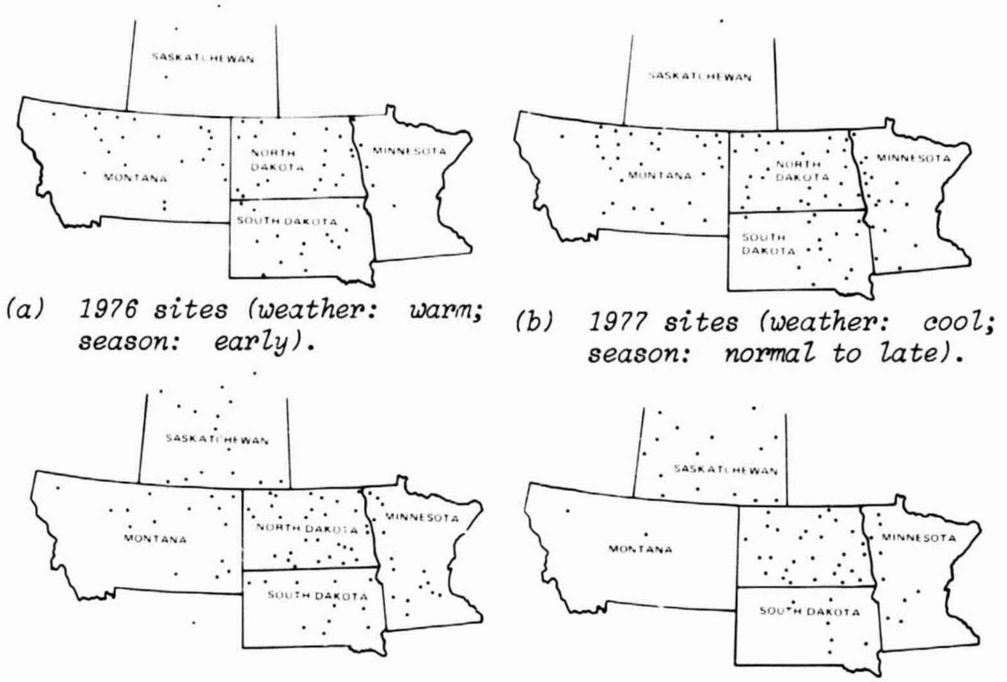
The results of these evaluations show the techniques to be highly efficient with greatly reduced analyst and computer processing costs, when compared to the previous manually intensive procedures (fig. 7), while still maintaining accuracies that are comparable to those obtained using previous historical spring small grains techniques (fig. 8).

These evaluations of this spring small grains area estimation technology established a sound technical basis for decisions to extend the research and development of these procedures to foreign environments (the U.S.S.R. and Australia) and to extend similar approaches to other crops and regions and to a multicrop estimation technology.

(Key references: FC-J1-04181; FC-J1-04087; FC-J1-04175, Vol. 1).

5.2.3 Estimation of Crop Areas — Corn and Soybeans

During 1980, the first year of AgRISTARS, exploratory experiments over Landsat data sites acquired



(a) 1976 sites (weather: warm; season: early).

(b) 1977 sites (weather: cool; season: normal to late).

(c) 1978 sites (season: early).

(d) 1979 sites (season: late).

Figure 6.- Site locations and meteorological summary for U.S. and Canada spring small grains.

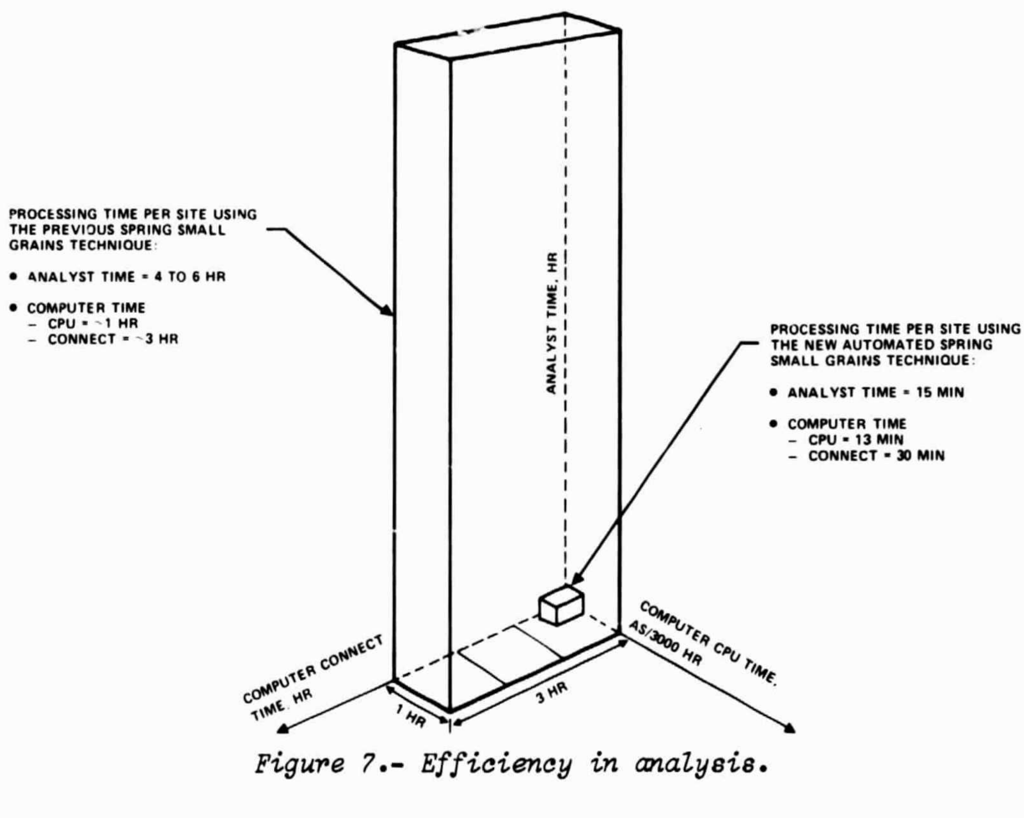


Figure 7.- Efficiency in analysis.

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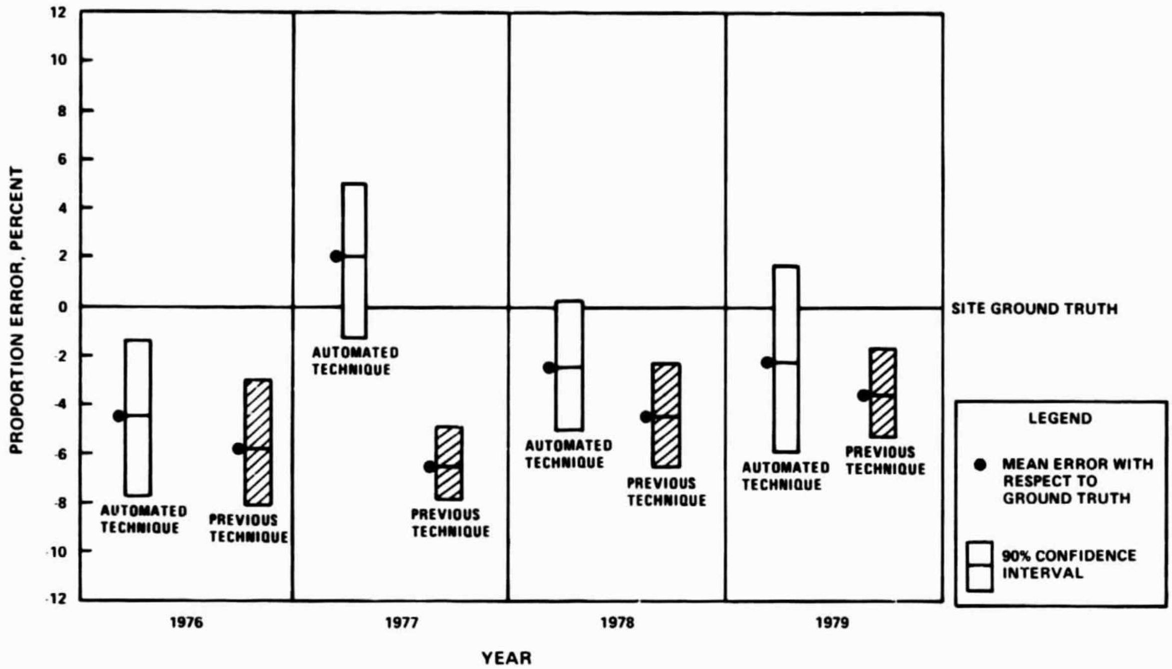

Figure 8.- Accuracy comparisons of ITD spring small grains techniques.

throughout the central U.S. Corn Belt in crop year 1978 showed that analysts using the then-current techniques provided quite accurate crop identification, especially for those Landsat pixels falling in the interior of agricultural fields. However, the accuracy of the crop proportion estimates obtained was considered disappointing in comparison to the excellent crop identification accuracy. This was felt to be caused largely by the small size of agricultural fields in the Corn Belt relative to the Landsat pixel. Consequently, research and development were focused on computer processing approaches for obtaining accurate proportion estimates in the presence of small fields while retaining the accuracy and objectivity of the 1980 crop identification technique. Of particular interest was the development of automatic techniques to identify agricultural fields in Landsat images and to extract crop planting and growing characteristics for use in objective crop identification logic.

During 1981, a baseline corn and soybean technique was established and evaluated using 2 years (1978-79) of Landsat and weather data over 23 sites in four states of the Corn Belt (fig. 9). The estimation of summer crop proportions (the logical group corresponding to spring small grains) showed virtually no error, with the estimates for both years within 2 percent of the ground estimates (fig. 10). Substantial improvements in bias and variance can be noted when compared to previous results. There was a tendency to overestimate corn and underestimate soybeans in the 2 years, but results were not statistically significant in 1979. Detailed analyses of the results indicate that minor modifications, now being completed, will reduce crop type proportion errors by one-half. The evaluation also indicated that a high proportion of the research sites was processable with the baseline technique (72 percent for crop group and 60 percent for crop type).

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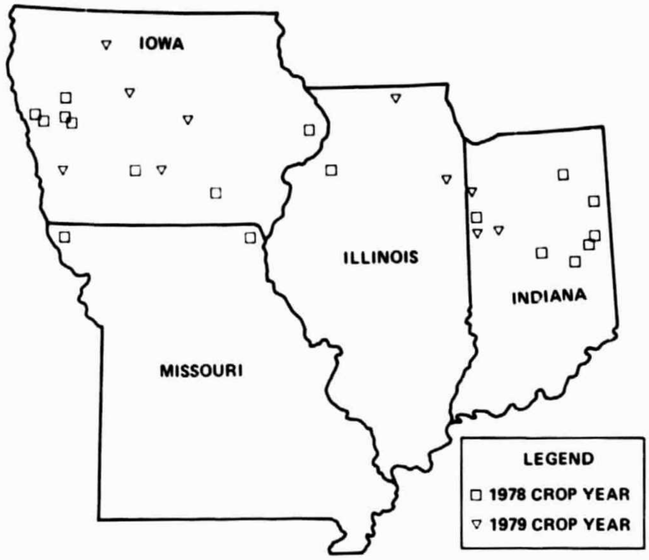

Figure 9.- Location of sites within the U.S. central Corn Belt for FY 1981 pilot experiment.

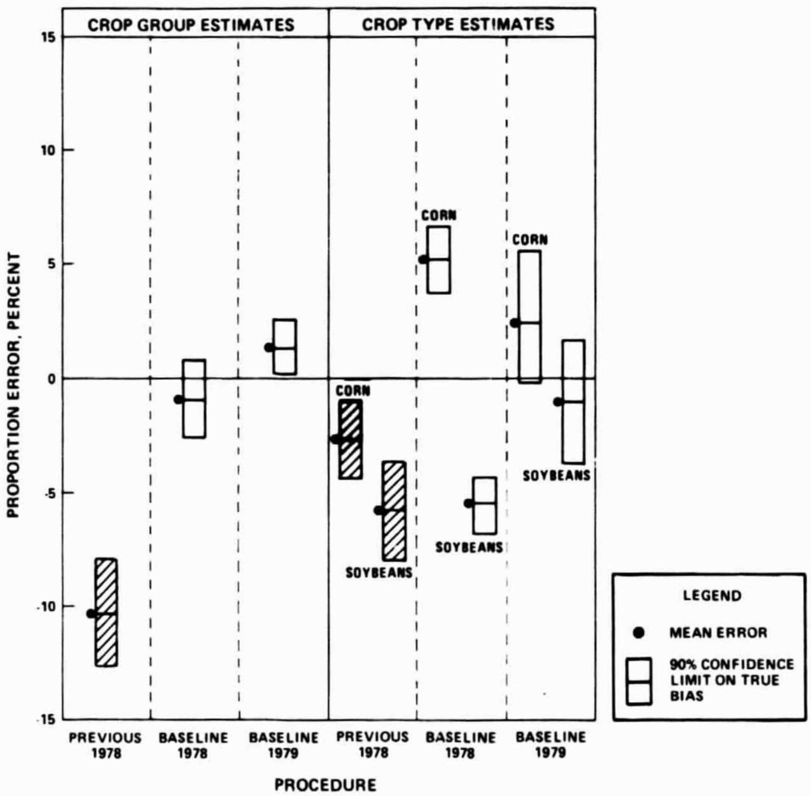

Figure 10.- Comparison of corn and soybean baseline subsystem with previous results.

The study also determined that the field labeling target is of key importance. In addition, the relationship between crop type and field size and the presence of crop stress, particularly in soybeans, were found to be significant factors in technique performance.

The baseline technique was implemented to permit tracing error sources rather than for efficiency. However, preliminary results in adapting one of the automated spring small grains techniques to corn and soybeans have proved highly encouraging, with highly accurate estimates of summer crop acreage (relative error of 0.4 percent) in early season (prior to crop emergence) and reliable corn and soybean acreage estimates about 1 month before harvest (relative errors of 7 and 9 percent, respectively) over 15 sites.

(Key references: FC-J1-04181; FC-J1-04087; FC-J1-04175, Vol. II; FC-J1-00504).

5.2.4 Simulation Developments

Estimating the performance of an area/production estimation system in foreign areas has always been a difficult problem. Among the major reasons for this problem are the lack of adequate foreign ground data or reliable regional area estimates coupled with the unknown sensitivity of analysis techniques to such factors as year-specific weather and different sample allocations. Many of these issues can be addressed with the use of an area/production estimation system simulator in conjunction with simulated Landsat data.

During the past year, the conceptual design of the system simulator (fig. 11) was completed, as well as detailed designs for several components. Technical development of the most critical component, an acquisition history simulator, is largely complete. This simulator is driven by the intersection of a Landsat satellite orbit model with a historical archive of cloud-cover data. This system will allow investigation of the effects of cloud cover on acquisition histories and, hence, on analysis results in ITD crop regions. Since actual historical cloud-cover data are input to the model, the spatial and temporal correlations in cloud cover and acquisition loss and, hence, in analysis error are preserved. The total system simulator can then be used to establish the efficiency of approaches for controlling errors in a large-area estimate. Again, the use of actual data permits investigation of the correlated effects of acquisition loss and other weather-driven effects, such as changes in crop calendars and crop yield.

ITD depends heavily on the use of Landsat and ground-truth data collected in regions of the United States that are similar to specific foreign crop regions for techniques research, development, and evaluation. However, no U.S. region can fully simulate the foreign region of interest (e.g., no U.S. region contains an equivalent amount of barley as a corresponding region in the U.S.S.R.). Therefore, a Landsat data simulation capability has been designed which allows the construction of simulated data sets by merging real data from several sites. This Landsat data simulator, which is in an advanced stage of development, will allow quantification of the effects of varying Landsat acquisition history, field size, crop mix, crop calendar relationships, crop condition, and other factors on analysis results.

Use of this Landsat data simulator in conjunction with the system simulator is expected to be the keystone in estimating the performance to be expected in foreign areas.

(Key references: FC-J1-00504, FC-J1-04181, FC-J1-04087, FC-L1-00634).

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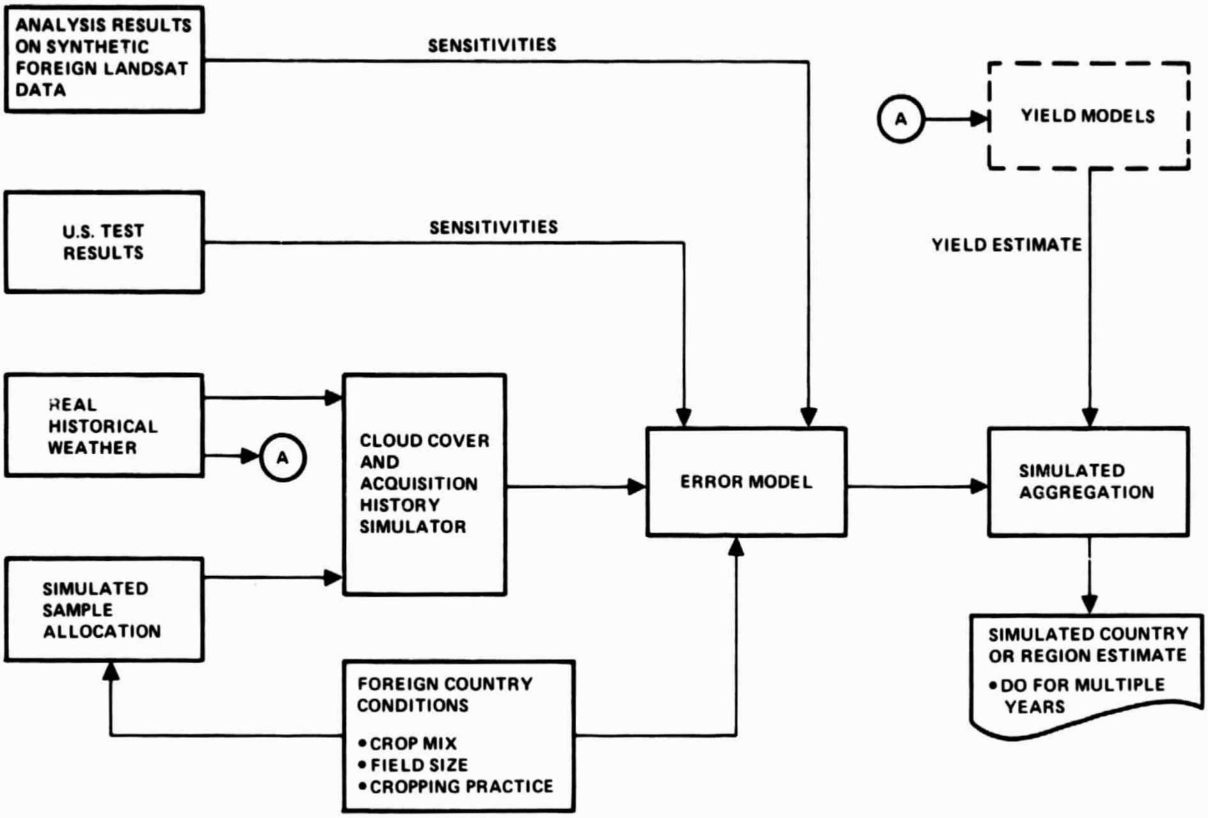

Figure 11.- Estimating performance in foreign areas through simulation.

5.2.5 Acquisition of Research Data

Extensive research data to support future research efforts were obtained in FY 1981. These data collections include:

- Correlated ground observations and coincidental Landsat imagery over 133 sites in four U.S. foreign similarity regions (fig. 12). These foreign similarity regions were selected on the basis of similarity of crop mix, climate, soil types, and terrain to the corn and soybean regions of Brazil and Argentina, wheat regions of Australia, and wheat and barley regions of the U.S.S.R.

- Partial ground-observation inventories and coincidental Landsat imagery for 16 sites in Argentina. These data were obtained with the assistance of the Argentina Government and the SR project.

- Landsat data obtained in Argentina, Australia, and Brazil for use in future research and development activities.

- Ground-observation data and Landsat imagery for six Australian segments from the crop year 1979-80. Also, plans have been developed for collecting ground-observation and Landsat data over 20 sites in Australia in FY 1982 in cooperation with the representatives of the Commonwealth of Australia.

(Key references: FC-J1-04181, FC-J1-04087, FC-J1-04108, FC-L1-04120, FC-J1-04130, FC-L1-00639).

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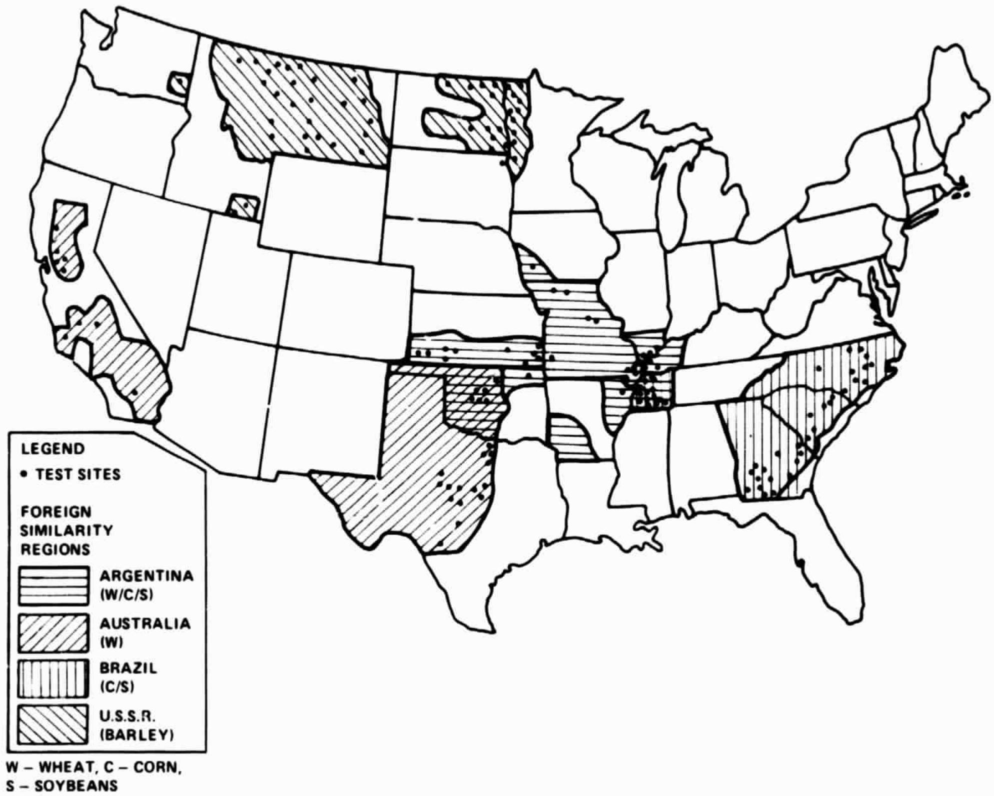

Figure 12.- FY 1981 foreign similarity regions.

5.2.6 Sponge, a Generalized Moisture Indicator

The crop moisture index (CMI) is currently used in many AgRISTARS projects to assess moisture conditions. It includes a two-layer soil water model and potential evapotranspiration calculated with Thornthwaite's method. Some of its requirements restrict its use to regions for which long-term average data, as well as current precipitation and temperature data, are available. An additional restriction inherent in the CMI is that it is an indicator of regional moisture for periods of at least a week and may give unreliable results when applied to a single station on a daily basis.

For these reasons, an evaporation model was developed which estimates monthly total evaporation in inches from vapor pressures corresponding to the mean monthly maximum and minimum temperatures. This result allowed the development of a simple moisture indicator with a sound physical basis that used common meteorological variables, was suitable over a broad range of climates, and was applicable to a single station. The resultant was named "sponge." Figure 13 shows a conceptual illustration of sponge.

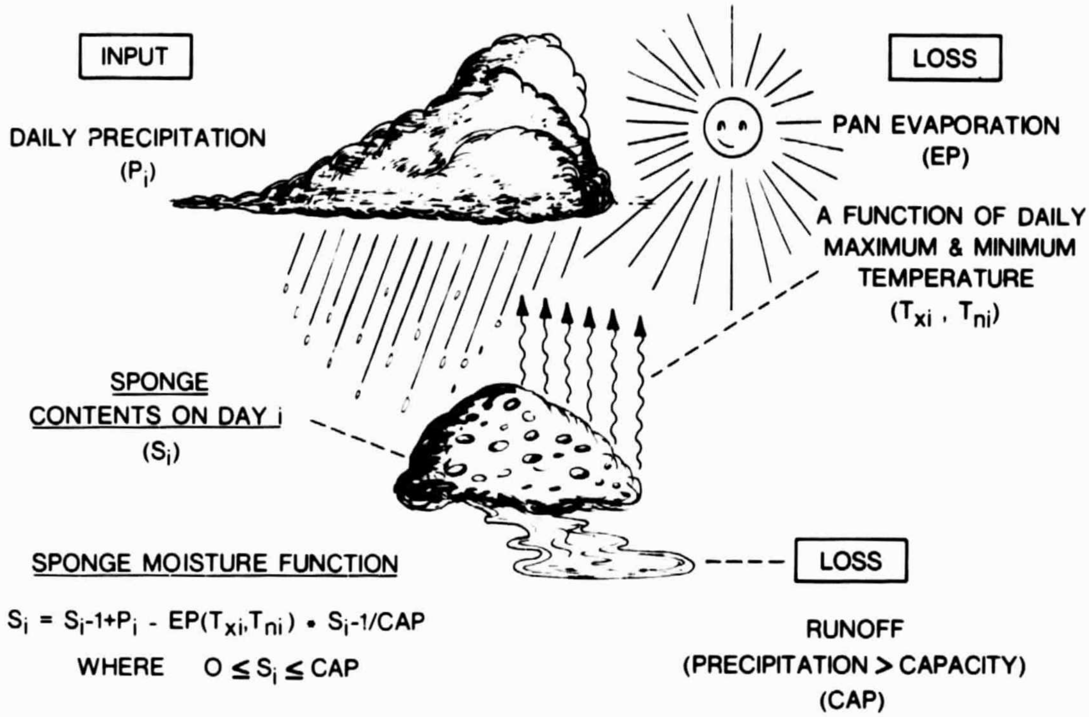

Figure 13.- The sponge moisture variable.

The sponge model is described as a simple medium with 8 inches of water-holding capacity which is initialized half-full of water 4 to 6 months prior to use. Each day, in accordance with the hydrologic cycle, water is added to the medium from precipitation and lost through evaporation. Precipitation (both liquid and frozen) is added at the full amount until the layer is saturated. It is this sponge-like behavior which gives the variable its name. Any additional precipitation is assumed to be lost as runoff or drainage.

Comparison for the year 1980 (fig. 14) indicated the incremental sponge values to be well correlated to range and pasture feed conditions (as reported in the USDA Weekly Weather and Crop Bulletin) over the U.S. Great Plains, U.S. Corn Belt, and Mississippi Valley.

(Key references: FC-J1-04087, FC-L1-04192).

5.2.7 Sample Frame Development Activities

A sample frame was created for selected geographic areas in Brazil to support the development and testing of area estimation methodology. The sample frame was developed for three provinces (Parana, Santa Catarina, and Rio Grande do Sul) and was constructed in a manner that would maximize sampling efficiency for corn and soybeans.

Work units were divided into homogeneous areas based on Landsat imagery, field patterns, and soil type. Digitized homogeneous polygons were "registered" to a segment grid. The following characteristics of each potential segment were specified: percentage of cultivated area, percentage of area devoted to corn or soybeans, field size, and soil type. Both segment unit information and polygon information are stored in Statistical Analysis System (SAS) data set form. Development of a sample frame for selected crop regions in Argentina is currently underway.

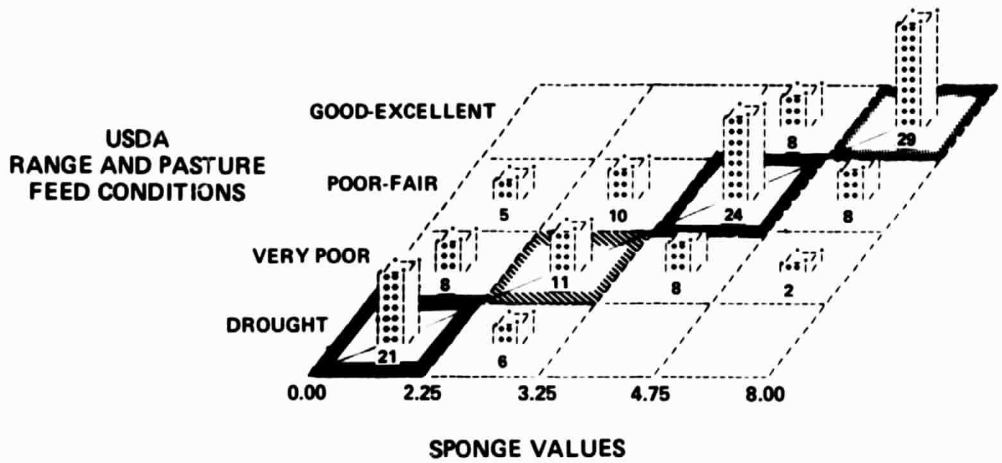

Figure 14.- Relationship of sponge values to 1980 range and pasture conditions.

5.3 YIELD MODEL DEVELOPMENT

5.3.1 Technical Objectives

The general objective of the YMD project is to develop improved yield estimation techniques for use in forecasting crop production in foreign and domestic areas. The focus of this effort in FY 1981 was on:

- Selecting the most accurate regression yield model for each of four crops (barley, corn, soybeans, and wheat) over selected areas of the United States.
- Providing the required yield estimates to ITD for crop production estimation.
- Estimating solar radiation from data provided by the metsat series of satellites.
- Acquiring crop growth simulation model documentation and data to test these models.
- Developing a soybean growth simulation model for yield estimation.

5.3.2 Selection and Evaluation of Yield Models

Available regression yield models were tested at the Joint Modeling Center in Columbia, Missouri. Joint recommendations by NASA, NOAA, and USDA personnel were made to the ITD project manager for the use of two barley, one corn, one soybean, and one wheat model for production estimation.

Monthly yield estimates for two crop years for wheat and barley and one crop year for corn and soybeans were provided to the ITD project manager.

5.3.3 Acquisition and Testing of Yield Models

Wheat growth simulation model documentation was obtained from five researchers and installed on a USDA computer network by a joint ARS-SRS group in Fort Collins, Colorado. Two of these models were tested, and recommendations for improvement were made to the developers based on evaluations completed.

Crop-growth, weather, and yield data were obtained from several ARS sites around the United States for testing. Access to U.S. Air Force satellite-enhanced agricultural-meteorological (agromet) data for current real-time testing has been arranged.

5.3.4 Meteorological and Climatological Data

Historical daily data (1974-79) from some 2500 reporting stations worldwide were assembled by the National Climatic Center (NCC), EDIS, and NOAA. Data for earlier years (1964-73) are being processed.

Current solar radiation measurements from GOES satellites were produced by the National Environmental Satellite Service (NESS) and evaluated by EDIS.

5.3.5 Improvement of Plant Process Models

Nutrient and water uptake submodels have been incorporated in a corn simulation model. A wheat simulation model was adapted to barley. Moisture stress and energy inputs are being related to photosynthesis in soybeans.

5.4 SUPPORTING RESEARCH

5.4.1 Technical Objectives

During FY 1981, the major thrusts of the SR project were focused on measurements, preprocessing, and automated information extraction techniques required for developing an efficient and accurate crop acreage estimation technology and crop condition assessment technology. Improved methods are under development for monitoring crop condition and estimating crop acreage to support production forecasts of small grains, corn, and soybeans in foreign areas. To support this effort, research is being performed in the areas of crop identification, crop area estimation, crop stage of development, and use of spectral inputs to assess crop condition.

5.4.2 Development of a Wheat Stress Index Model

The wheat stress index model relates the daily crop moisture stress of wheat and its phenological development. The model was developed using improved thermal and photothermal responses and by adding a moisture stress index variable to account for the effect of moisture on phenology. The model also has the capability to accept spectral data as an input for estimating planting date, leaf area index, and soil moisture.

The wheat stress index model has two main components; namely, a biological clock that generates the phenological progression of the crop and a daily crop moisture stress index (fig. 15). Crop phenology is modeled from temperature and photoperiod responses of the crop from emergence to physiological maturity. The influence of the crop moisture deficit condition on phenological development is an important input parameter to the model which simulates the slowing down and hastening effects on development due to moisture stress. The crop moisture stress index is derived from simulation of water relations in the soil-plant-atmosphere continuum. The stress index reflects the moisture deficit condition of the crop relative to the available soil moisture, the evaporative demand of the environment, and the crop water requirements at a given stage of development.

Evaluation of the wheat stress index model, including a comparison with the Robertson Biometeorological Time Scale model, has been completed using an independent data set acquired over the U.S. northern Great Plains during the 1980 crop year. The two models were initiated using the same form for predicting emergence dates. The predicted emergence dates were found to be well correlated (r = 0.97) with the ground-observed emergence dates for each of the 204 fields with no indication of bias. The growth-stage predictions for both models were well correlated with the ground-observed estimates of growth stages from tillering through maturity. However, the wheat stress model provided significant improvement over the Robertson model based on a field-by-field growth stage error analysis. Eighty percent of the wheat stress model estimates were within 0.5 stage of the ground-observed estimates, while only 68 percent of the Robertson model estimates were within 0.5 stage. The improvement occurred primarily in the heading and seed development stages for spring wheat. High accuracy for these stages is especially important for crop identification using remotely sensed data and for yield estimation, since stress during these stages can reduce yield by as much as 50 percent. The model has been requested by USDA for evaluation for use in their operational system. Further improvements to the wheat stress model are anticipated by incorporating spectral data to estimate planting date, leaf area index, and soil moisture.

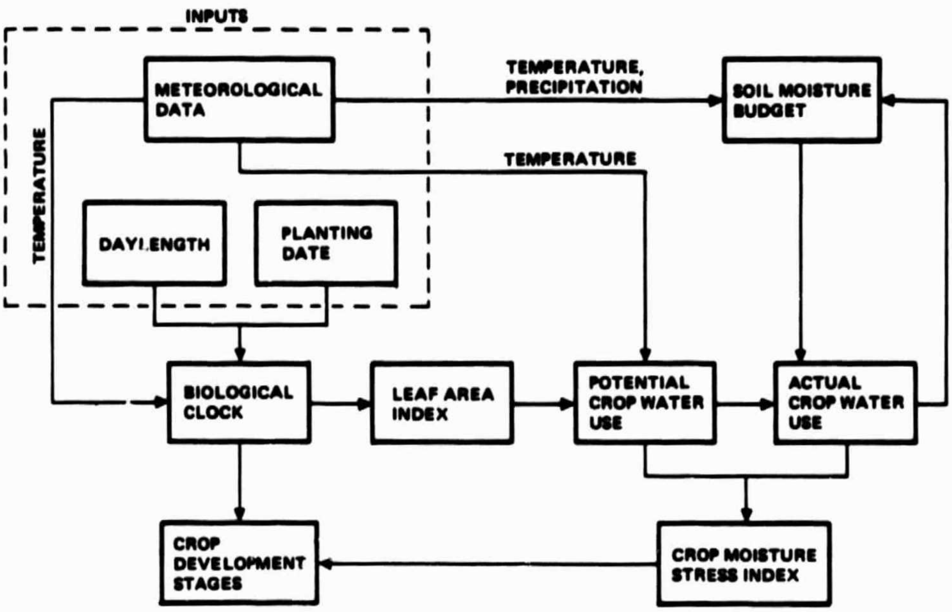

Figure 15.- Simplified diagram of the flow of the wheat stress indicator model.

5.4.3 Simulation of Spacecraft Sensors

This effort is important not only for projecting the performance of new spacecraft sensors such as the TM prior to launch but also in evaluating the sensitivity of information extraction algorithms (e.g., crop identification, crop condition, and crop stage) to the varying conditions under which the data are taken. With use of the simulated data, selected variables can be held constant, while the variable of interest is changed, and the sensitivity of the algorithm evaluated. For example, the impact of impure pixels (which include portions of more than one field) on classification performance can be examined as a function of registration error. Similarly, the effect of acquisition loss (due to cloud cover, etc.) at various times during the season on the accuracy of the information extraction algorithm can be examined.

Simulation of spacecraft imagery over agricultural areas requires the field structure, sensor response, crop reflectance distribution, atmospheric characteristics, and cropping practices to be modeled. Two approaches have been used in the SR project for generating the simulated TM data. In the first approach, an aircraft scanner (NS-001), which is similar to the TM, was used to collect data over a corn and soybean area in Webster County, Iowa. These data were then scan-angle corrected, calibrated, rectified, and resampled so that the data closely approximated TM data (fig. 16). This approach has the advantage that true agricultural field boundaries are maintained and that true variability within and between fields is observed. However, it has the disadvantage that the aircraft data must be corrected for scan angle, etc., and that numerous aircraft missions must be flown to simulate a crop year.

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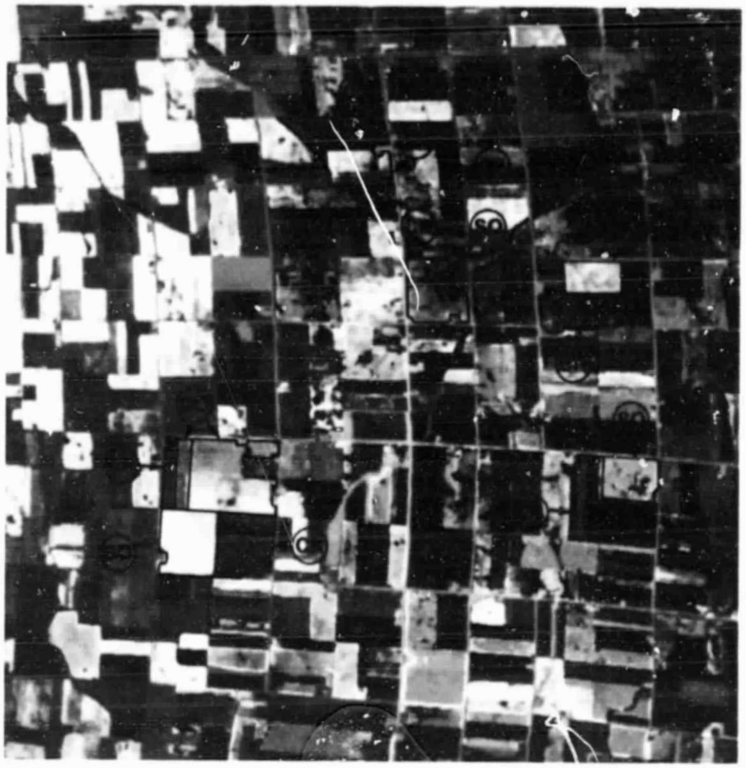

Figure 16.- Simulated TM data (2.08 to 2.35 micrometers) for Webster County, Iowa, on August 30, 1979.

The second approach involves modeling and simulation based on field spectrometer data. The data are first converted to the TM bands, calibrated, and a raster scan of the data at TM and MSS resolutions displayed using field boundaries derived from aerial photography. To use this approach, realistic estimates of within and between field variability must be incorporated in the models. Using these field variability models, one can control characteristics of the scene such as the spectral distribution of each crop, the spectral distribution of the boundary (or mixed) pixels, and the field-size distribution. Acquisition dates can be simulated to reduce the large number of aircraft flights by incorporating a temporal model of the crop reflectance. Figures 17 and 18 show images generated using this technique at Landsat TM resolution versus MSS resolution for a small grains and corn area in Kingsbury County, South Dakota. The improved resolution of the TM shows much improved field boundaries, especially for the strip/fallow and small fields. Research has shown that 75 percent of the crop pixels will be pure for TM scenes, whereas only 35 percent of the crop pixels will be pure for the MSS scenes (fig. 19).

Research is also underway to merge these two simulation approaches with a third type which uses a crop reflectance model and a crop development model or growth model. This will allow even more flexibility in performing sensitivity analyses of crop scenes since the crop profile will be generated without assuming the applicability of an empirically derived temporal model. Sensitivity studies of crop reflectance to leaf area

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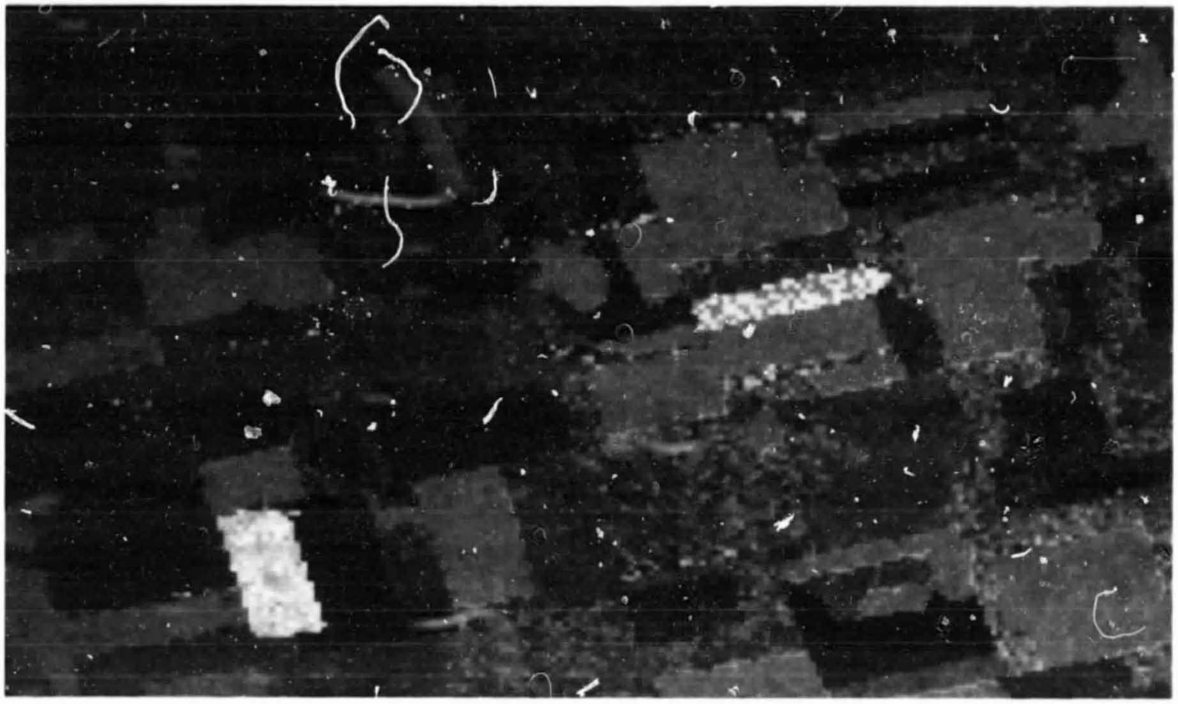

Figure 17.- Simulated TM scene of a spring wheat segment. (Blue, green, and red represent TM channels 2, 3, and 4.)

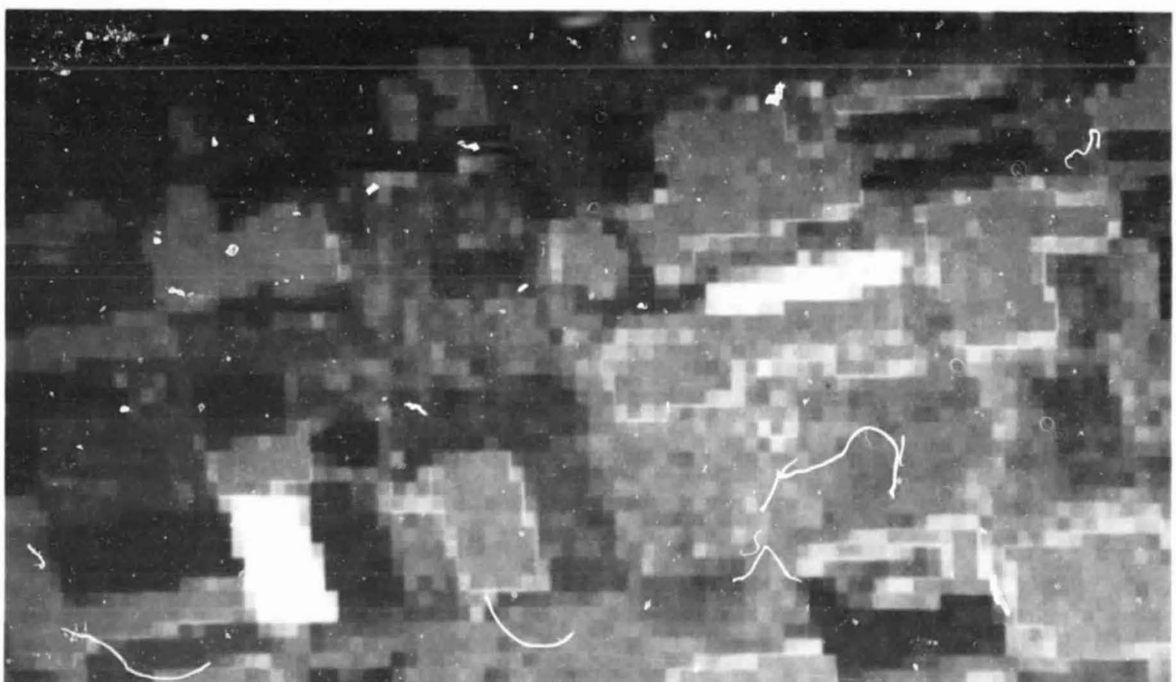

Figure 18.- MSS scene of a spring wheat segment. (Blue, green, and red represent MSS channels 4, 5, and 7.)

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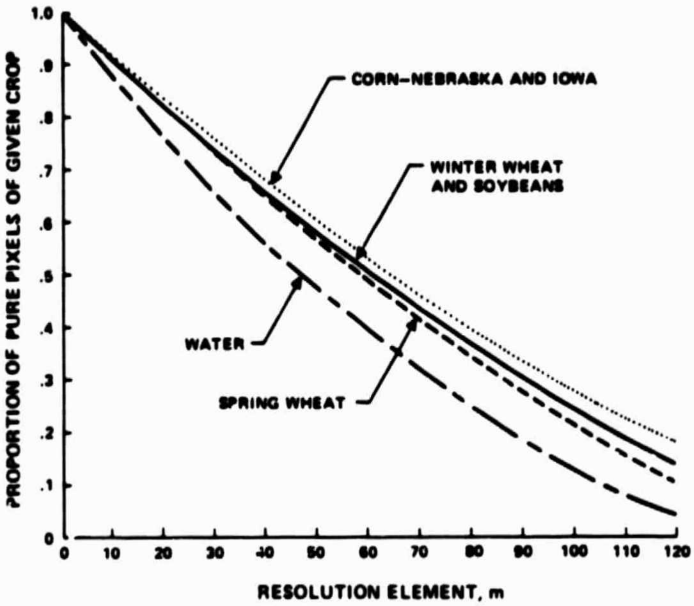

Figure 19.- Proportion of a crop in pure pixels as a function of sensor resolutions.

index, biomass, water stress, etc., will then be feasible with only minimal aircraft and field spectrometer data. In the near future, these simulation tools will be used to investigate the effect of the boundary pixels on classification performance, the temporal sampling effect on classification performance, and the improvements of TM over the MSS in terms of classification performance.

5.4.4 Advanced Proportion Estimation Procedure

The Advanced Proportion Estimation Procedure (APEP) for estimating a crop acreage without requiring manually identified training samples is being developed. The estimates for this approach can be unbiased as a consequence of abandoning previously used classification approaches in favor of a "direct" method for estimating crop acreage.

The major functional elements of APEP are shown in figure 20. By using models of crop growth (called profile models), successive Landsat acquisitions of data over time are transformed into a sequence of growth variable values. These transformations reduce extraneous effects of the data that are irrelevant to crop identification. A statistical model (called a mixture model) is then used to estimate directly the proportions of the crops of interest in the Landsat scene. To complete the process, each proportion estimate must be given a crop name. This is referred to as the labeling

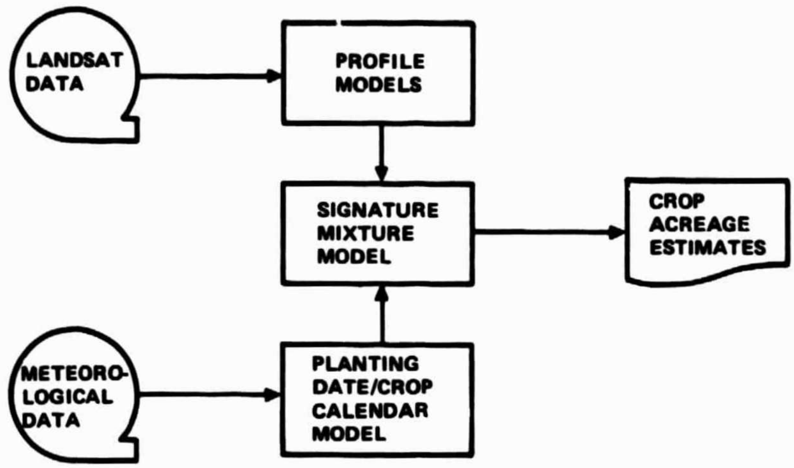

Figure 20.- Advanced Proportion Estimation Procedure.

function. Labeling is achieved by associating a predicted growth curve for a given crop, as derived from meteorological data, with one of the growth curves estimated from the mixture model.

In the FY 1980 AgRISTARS Annual Report, the crop spectral-temporal profile was introduced. The profile is a mathematical representation of Landsat multidate data. This representation of the MSS data permits an extraction of agronomically significant features of the crop such as planting date, growing-season length, and rate of greenup and senescence. The area estimation procedure, based on these agronomic variables, has been developed for the separation of corn, soybeans, and other. It has been implemented and tested on data acquired in 1978 and 1979. Results of the verification tests show a nearly unbiased estimate of the three crop categories.

Figure 21 shows a histogram of the rate of greenup calculated from Landsat MSS data acquired over an AgRISTARS segment in Iowa in 1978. This shows clearly the separation that is possible between the three categories. Using various other variables calculated from the Landsat, the analyst can objectively and in very short time (less than 1 hour) label 15 to 20 pixels per class. A linear classifier is trained on these pixels, and decision planes defining the crop categories are determined. Using these planes, each pixel is then classified. This technique shows promise of complete automation and indicates that area estimation as early as 60 days after corn planting is possible.

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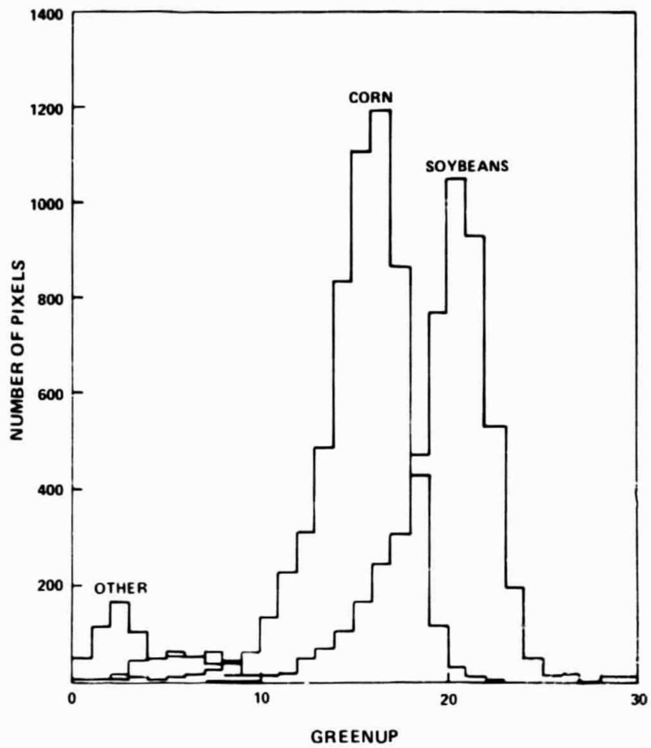

Figure 21.- Histogram of the rate of greenup for corn, soybeans, and all other.

5.4.5 Registration

In the Large Area Crop Inventory Experiment (LACIE), registered multi-date MSS data were provided by the Goddard Space Flight Center (GSFC) LACIE processor. This system provided registration at the level of 1974 state-of-the-art technology. Many of the AgRISTARS applications are poorly served by that accuracy of approximately 1 pixel. AgRISTARS is now using data processed at GSFC and further refined by the registration processor at the Johnson Space Center (JSC). Preliminary estimation of the registration accuracy with this combined system is at or below 0.5 pixel. Further improvements toward the goal of 0.2 pixel accuracy are in work.

In summary, the 1981 effort in supporting research has resulted in substantial technical progress and has placed the project in a strong position to initiate the work to be performed in subsequent years.

5.5 SOIL MOISTURE

5.5.1 Technical Objectives

The principal objective of the SM project is to gain a fundamental understanding of the dynamic properties of soil moisture and to develop the capability of predicting moisture conditions over large areas. The ultimate goal is to specify (but not implement) an operational soil moisture measurement system that can accurately, and in near real time, provide soil moisture data in the root zone of soils over large land areas.

Specific technical objectives during FY 1981 focused on the following:

- Sensor development and evaluation.
- Collection of field data, both ground and airborne, to assess predictive models.
- Modeling and remote sensing data analysis.

5.5.2 Summary of Accomplishments

Significant progress has been made in the AgRISTARS SM project since its inception toward meeting the goal of developing technology to estimate soil moisture profiles from remotely sensed and ground sensor data. Major results have been:

- The impact of soil temperature and soil texture on microwave soil moisture measurements has been resolved. Figure 22 shows that the Jet Propulsion Laboratory (JPL) model and the GSFC model produce results that agree with observed microwave brightness temperatures in two significantly different locations.

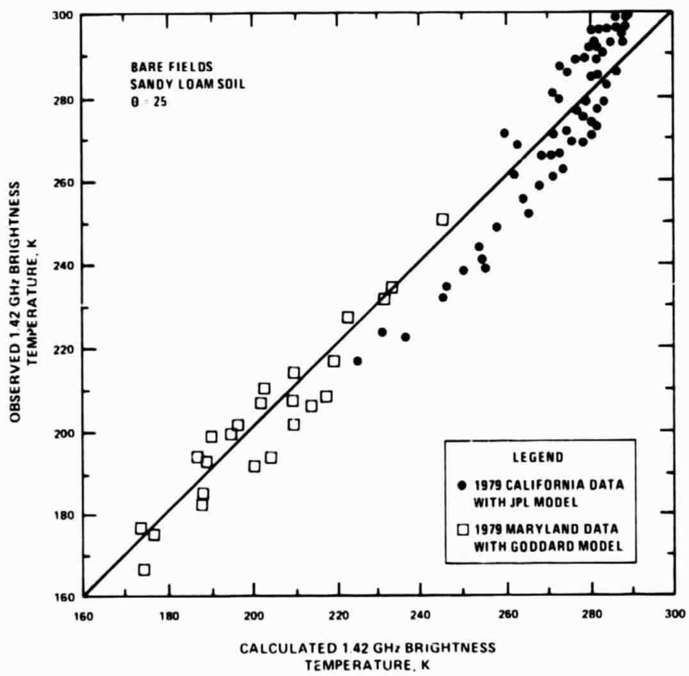

Figure 22.- Comparison of model results using California and Maryland data taken in fields with similar soil textures. (The figure includes both horizontal and vertical polarization.)

- Roughness effects in terms of surface height variations and horizontal correlation are understood. Figure 23 illustrates the agreement between backscatter theory and measurements for three different roughness scales.

- The effects of vegetation on microwave soil moisture measurements have been quantified. Figure 24 shows that vegetation must be considered when volumetric moisture content (in grams per cubic centimeter) is calculated from brightness temperatures and that approaches to consider vegetation have been developed. Figure 25 is a further indication of this fact.

- Substantial agreement has been found between theory and measurement of the penetration depth (the depth of soil moisture effects) of microwave signatures at X-, C-, and L-bands. A comparison of the graphs in figure 26 shows that the percentage of estimated gravimetric soil moisture agrees with the measured 0- to 2-centimeter dry-down curve. There is also a diurnal variation of sampling depth that varies within the 0- to 2-centimeter region. It appears that time of day may be an important consideration in remote sensing of soil moisture.

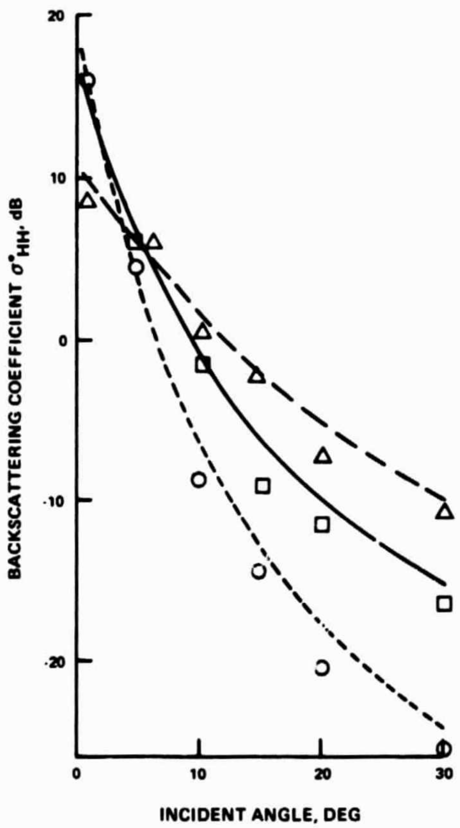

Figure 23.- Comparisons between theory and backscatter measurements from soil surfaces with three different roughness scales at 1.1 gigahertz.

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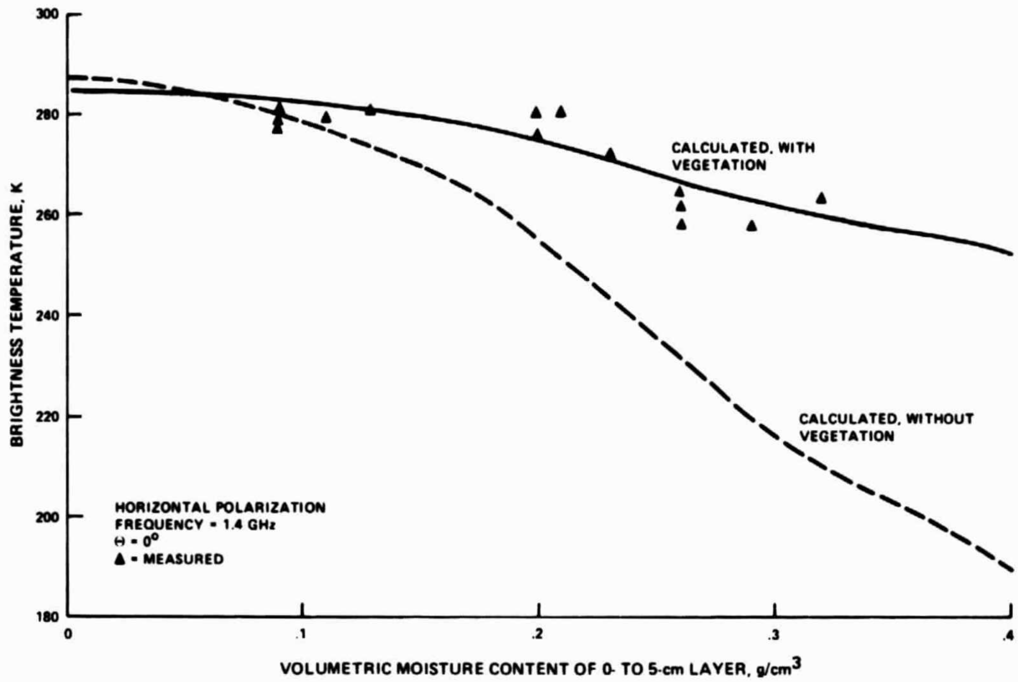

Figure 24.- The effect of vegetation on calculated volumetric soil moisture content.

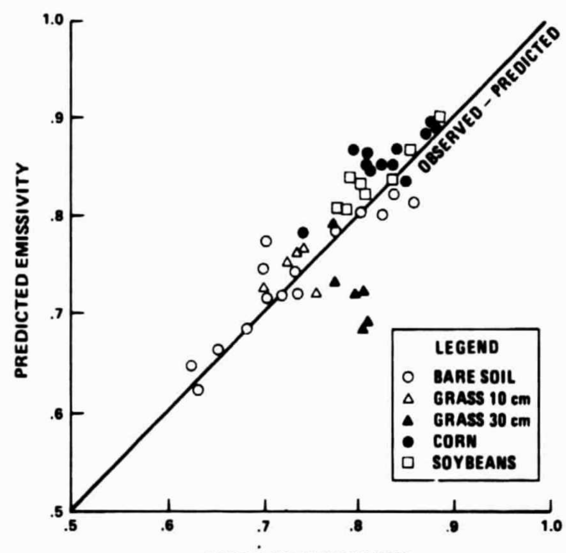

Figure 25.- Accounting for vegetation effects in emissivity model by using the water content of vegetation. (The observed and predicted emissivity values were made at the Beltsville Agricultural Research Center using the water content model.)

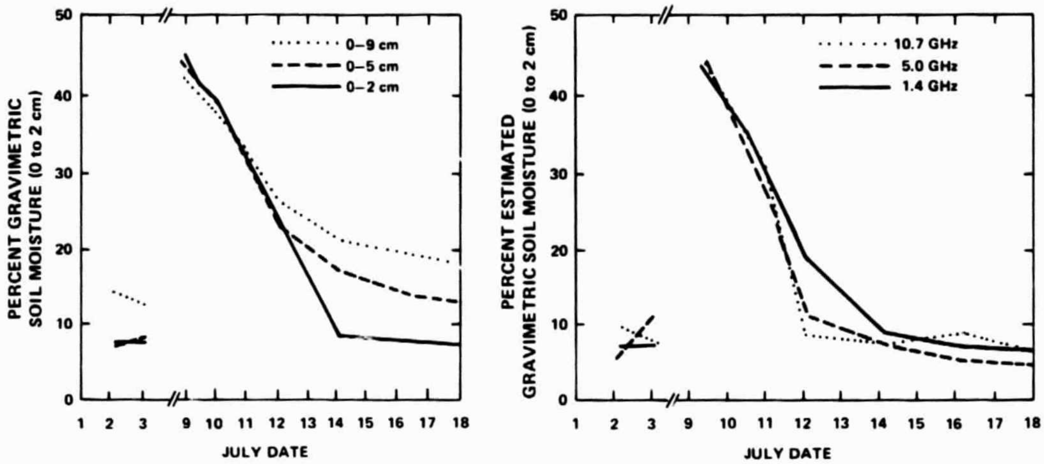

Figure 26.- A comparison of soil moisture and microwave dry-down curves in a smooth field.

- A preliminary resolution analysis has started. Initial results indicate that a 100-meter resolution is probably the minimum resolution that would be required for regional soil moisture determination.

- Ground Scatterometer System (GSS) data were analyzed to determine the nature of row-structure and row-direction effects on L-, C-, and X-band measurements.

- Procedures were developed to allow the testing of soil moisture estimation algorithms driven by remotely sensed data.

- A model to predict the soil moisture characteristic (water tension versus volumetric soil moisture content) from particle-size distribution and bulk density data was refined and tested against about 190 measured data sets.

- Experiments were initiated to study the relationship between surface-zone soil moisture and winter wheat and sorghum yields for corn and soybeans, as well as the relationships between surface-zone soil moisture, surface flux, and subsurface moisture conditions.

- Initial requirements were determined for a nuclear magnetic resonance (NMR) - a technology using magnetic fields to identify specifications - soil moisture measuring instrument, and a proposal for its construction has been accepted. A prototype of this instrument will be ready for preliminary testing during FY 1982.

- A bibliography of soil moisture research has been started. Although it is not in a publishable form yet, there are about 800 citations listed. This work will continue during FY 1982.

- A soil-plant-atmosphere-water model (called SPAW) was verified by running it against known amounts of soil moisture for 2 years. Calibration of the model appears to be quite accurate. Verification of the model run with data from six different areas of the country will be done in FY 1982.

5.6 DOMESTIC CROPS AND LAND COVER

5.6.1 Technical Objectives

The principal aims of the DC/LC project are (1) the evaluation of research techniques for area estimation and development of an operational procedure for crop acreage estimation and (2) the development of remote sensing techniques to satisfy the land cover information needs of USDA.

Technical objectives during FY 1981 focused on the following:

- Developing, testing, and evaluating operational procedures for estimating the acreages of major crops over large areas, such as at the state level.
- Assessing and improving current techniques, such as automatic digitization, for registering and processing data.
- Conducting a first-time study which integrated basic land cover definitions into a USDA operational survey in order to estimate land cover acreages.
- Conducting simulation studies on the performance of new spaceborne sensors.

5.6.. -timation of Acreage of Major Crops

Information on field locations (crops or land cover) and acreage derived from the USDA/SRS June Enumerative Survey (JES) provided the ground-truth data for correlation with Landsat data. During FY 1981, data from Iowa, Kansas, Missouri, and Oklahoma were employed in the effort to develop operational techniques. Slight changes to the field survey procedures were needed to identify continuous areas of wasteland in crop fields and to extract the reported information in a unique field-identified format.

For the 1980 crop year, estimates of harvested winter wheat acreage in Kansas and planted corn and soybeans acreages in Iowa were calculated by combining available Landsat data with ground data. These data were utilized by the USDA Crop Reporting Board. For the 1981 crop year, estimates of harvested winter wheat acreage in Kansas and Oklahoma and of planted corn and soybean acreage in Iowa and Missouri were made utilizing Landsat digital data in combination with ground data. For the 1982 crop year, two additional states, Colorado (for winter wheat) and Illinois (for corn and soybeans), will be added to the project. The operations implemented in Iowa, Kansas, Missouri, and Oklahoma in 1981 will also be resumed.

5.6.3 Evaluation of Accuracy of Multitemporal Registration

Use of scene-to-scene registration for multitemporal classification should provide improvement over single-date classification for crop acreage estimates and the detection of land cover change over time. The goal is to attain registration accuracies of 40 meters root mean square error (RMSE) for a uniformly distributed network of 200 points falling over 85 percent of a scene. Both the USDA/SRS and the NSTL/ERL have developed procedures for overlaying and registering sequential Landsat passes.

In order to represent various surface conditions, 3 test sites were chosen within each of 4 general land use categories, for a total of 12 test sites. The principal accomplishment during FY 1981 was the implementation of procedures to

calculate the errors in positional accuracy for scene-to-scene registration of two dates for each of the 12 test sites and to compare the results from both procedures for 8 of the sites. (See table 1.) The NSTL/ERL registration accuracies ranged from 16 to 40 meters RMSE, with an average of 31.6 meters. The USDA/SRS procedure resulted in accuracies at the 40-meter target. The NSTL/ERL results were significantly more accurate for five of the eight scenes; for these five scenes, the average accuracy improvement was 10 meters RMSE.

5.6.4 Evaluation of Current Scene-to-Map Registration Accuracy

The registration of Landsat data to a map (and thereby to the ground) is essential for deriving accurate information from Landsat. The current USDA/SRS procedure involves two stages of registration. Automatic procedures are being evaluated as possible replacements for either or both stages.

During the last year, a study was made to determine the accuracy of the P-format registration provided by the Hotine tick marks of the computer-compatible tapes (CCT's). The results of this study are documented in AgRISTARS report DC-Y1-04069, entitled "An Evaluation of MSS P-Format Data Registration."

During FY 1981, an algorithm was developed that enhances field boundaries within the Landsat data. This algorithm is part of the process used in developing the Automatic Segment-to-Map Algorithm (ASMA). As a test, 20 segments from Landsat scene 21980-16264 were shifted manually by two USDA/SRS analysts and by ASMA. The results from ASMA for 17 of the 20 segments were either identical or very close to shifts by at least one of the analysts. However, the algorithm gave very misleading results in the other three cases, and modification is needed to identify these "problems."

5.6.5 Improvement of Clustering and Classification

During FY 1980, DC/LC determined that CLASSY (a classification software package developed by NASA/JSC) showed a significant improvement over the procedures used by USDA/SRS at that time to cluster data of a specific crop. In FY 1981, the CLASSY procedure was installed in the USDA/SRS EDITOR software system and used successfully for all classifications. The results indicate that CLASSY required higher computer processing unit (CPU) resources than expected. Training set selection procedures were reevaluated, and possible efficiencies will be explored in FY 1982.

5.6.6 Land Cover Classification/Mapping Algorithms

Multiband, multitemporal, and transformed Landsat MSS data sets were analyzed using pattern recognition procedures employed by USDA/SRS and NSTL/ERL for the purpose of land cover area estimation. The analyses had in common the use of field-verified land cover data for training and accuracy testing in the form of 33 JES segments, typically 2.5 square kilometers in size. Corn, soybeans, hay/permanent pasture, and dense woodland predominate in the landscape of the 11-county north-central Missouri test area and were the four land cover types studied.

Multitemporal data sets gave significantly higher classification accuracies than any single-date Landst data set for

TABLE 1.- COMPARISON OF TEST RESULTS FOR TWO MULTITEMPORAL REGISTRATION PROCEDURES

Land cover type	Accuracy, m		F-test results,[a] NSTL/ERL vs USDA/SRS
	NSTL/ERL	USDA/SRS	
Agriculture			
Arizona	35.008	43.521	Significant
South Dakota	26.916	42.753	Significant
Missouri	40.401		
Range			
Kansas	37.603	38.813	Not significant
Idaho	31.810	46.058	Significant
Oklahoma	28.320		
Forest			
Colorado	36.875	39.035	Not significant
South Carolina	33.488		
Idaho	25.741	32.575	Significant
Mixed			
Kentucky	32.894	39.552	Not significant
North Carolina	33.691	38.447	Significant
Mississippi	16.236		
Average	31.582	40.094	

[a]The hypothesis is H_0: $\sigma^2_{SRS} > \sigma^2_{ERL}$, $\alpha = 0.10$

data processing procedures used by both USDA/SRS and NSTL/ERL. (See table 2.) Multitemporal analysis using only Landsat MSS bands 5 and 7 showed no significant difference in overall classification accuracy from analysis using bands 4 and 6 in addition to bands 5 and 7. Transformed data sets also failed to improve classification accuracies significantly, but rather served as a means of reducing data from four to two channels, thus decreasing processing time.

5.6.7 Change Detection and Monitoring

Sites were specifically selected for evaluation of change detection techniques including one in Louisiana where bottomland forest is being converted to cropland, a second in southwestern Kansas where rangeland is being converted to irrigated cropland, and a third in central Arizona where rangeland and cropland are being converted to urban residential use.

Four methods of change detection in cropland areas have been developed and are currently being evaluated:

- Postclassification differencing - Spectral data from two different dates are reduced to user-defined land cover groupings via automated signature development and maximum likelihood classifier algorithms. These two dates are then registered cell to cell and compared for changes in specific land cover distributions.

TABLE 2.- ELAS[a] CLASSIFICATION RESULTS FOR FIVE MULTIBAND, MULTITEMPORAL, AND TRANSFORMED LANDSAT DATA SETS FROM ANALYSIS OF 33 JES SEGMENTS IN NORTH-CENTRAL MISSOURI

Land cover category	Aug. 2 channels (5, 7)			May/Aug. 4 channels (5, 7/5, 7)			Aug./Sept. 4 channels (5, 7/5, 7)			May/Aug./Sept. 6 channels (5, 7/5, 7/5, 7)			Aug./Sept. 4 channels (B, G/B, G)[b]		
	Spectral classes	PCC[c]	Commission error, %	Spectral classes	PCC[c]	Commission error, %	Spectral classes	PCC[c]	Commission error, %	Spectral classes	PCC[c]	Commission error, %	Spectral classes	PCC[c]	Commission error, %
Corn	5	59.1	62.1	10	74.8	22.0	8	78.0	20.9	12	76.5	13.7	5	81.0	25.6
Soybeans	7	56.4	29.7	21	81.5	24.2	16	84.9	16.7	15	82.5	14.1	11	77.4	26.4
Hay/ permanent pasture	13	71.4	29.3	24	79.9	15.2	24	85.5	14.5	21	88.7	17.6	11	71.9	28.1
Dense woodland	2	30.0	49.8	3	58.9	48.2	4	60.3	30.4	3	63.7	29.6	2	71.4	52.2
Overall	27	62.1	37.9	58	78.0	22.0	52	82.3	17.7	51	83.1	16.9	29	74.8	25.2

[a]NSTL/ERL software classification package.

[b]Brightness and greenness components of the Kauth-Thomas transformation.

[c]Percent correct classification.

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- Composite classification direct change - Scenes from two dates are registered and then classified, producing a mapped area of change classes which are then named as to type of change.

- Radiance value shift - Data are overlaid for two dates and tested for distance and direction of changes in the cell-to-cell reflected signal response of various representative cover types.

- Regression model - A model is developed which best describes a prediction between time 2 (latest) data as a function of time 1 (oldest) data. The determination of a threshold value allows each pixel to be designated a change or no-change status based on the relative position of its value with respect to the threshold.

During FY 1981, each of these four methods was tested with Landsat MSS data acquired during 1974 and 1979 for the Louisiana site. Wall-to-wall land cover change was interpreted from color infrared aerial photography, field checked, digitized, and used to verify the accuracy of the change-detection methods. The results indicate that all four methods were adequate with respect to accuracy, as shown in table 3, with the main differences being the ease of implementation and usage time. Evaluations for the Kansas and Arizona sites are scheduled for completion during FY 1982.

Because the four previously outlined change-detection methods are mainly sensitive to changes in dense vegetation, a fifth method is being developed for monitoring land resource degradation in arid and semiarid rangelands.

TABLE 3.- ACCURACY TABULATION TABLE

Technique/variation	Agreement between Landsat results and aerial photointerpretation/ground truth						Disagreement between Landsat results and aerial photointerpretation/ground truth			
	No change		Change		Total agreement (no change + change)		Commission error		Omission error	
	Area, mi^2	Percent	Area, mi^2	Percent	Area, mi^2	Percent	Area, mi^2	Percent	Area, mi^2	Percent
Postclassification differencing	1744.0	85.8	184.9	9.1	1928.9	94.9	80.3	3.9	23.0	1.1
Composite classification										
4-channel	1768.1	87.0	185.5	9.1	1953.6	96.1	56.2	2.8	22.4	1.1
6-channel	1759.9	86.6	186.3	9.2	1946.2	95.8	64.4	3.2	21.6	1.1
8-channel	1767.2	87.0	184.4	9.1	1951.6	96.0	57.1	2.8	23.4	1.2
Radiance value shift	1722.2	84.7	153.6	7.6	1875.8	92.3	102.1	5.0	54.3	2.7
Regression model	1437.1	70.7	155.7	7.7	1592.8	78.4	387.2	19.1	52.2	2.6

5.6.8 Land-Cover Studies

Under DC/LC, the USDA has a requirement to develop procedures for identifying and monitoring land cover categories. During FY 1981, a land cover study was conducted in Kansas to estimate land cover categories with the operational JES of USDA/SRS and Landsat data. The definitions of land cover categories were successfully implemented in this special study and will be adapted again for the JES in Missouri in 1982.

5.6.9 Studies of New Sensors

In 1981, a TM simulator was used to analyze crop classification results that should be possible from the TM as compared to the MSS. An experiment was designed to study the effects of the additional bands, additional spatial resolution, and improved quantization.

The experimental data collected over northern Missouri indicate that both increased bands and better spatial resolution improved the classification results significantly, while the improved quantization did little to improve classification results.

TM data should greatly improve USDA/SRS crop acreage estimates if the data are acquired at optimum times.

5.7 RENEWABLE RESOURCES INVENTORY

5.7.1 Technical Objectives

The general objectives of RRI project activities are to develop, test, and evaluate methods for applying new remote sensing techniques to the inventory, monitoring, and management of forest and rangeland renewable resources. The particular technical objectives in FY 1981 were focused on:

- Improving methods for the collection, display, and use of resource information for forest management and planning.
- Evaluating Landsat technology as a tool for supporting multiresource inventories and forest planning.
- Demonstrating the capability to monitor, classify, and measure disturbances and changes in forests and rangeland.
- Improving the capability to map and characterize natural and managed habitats.
- 'mproving the capabilities of high-altitude sensors.

5.7.2 Forest Management and Landsat Evaluation

The plan for the final phase of the Multiresource Inventory Methods Pilot Test has been written. This phase will be conducted on a test site in Idaho in FY 1982.

During FY 1981, several studies were conducted to support forest management and Landsat evaluation:

- Quantitative evaluation of two different clustering algorithms, the Iterative Self-Organizing Clustering System (ISOCLS) and CLASSY, was performed using Landsat MSS data on a site in northern Idaho.
- Land management planning requirements were defined for the San Juan National Forest in southwestern Colorado. An implementation plan was developed so that an efficient and effective system of resource data management, utilizing remote sensing and other techniques, can be designed and implemented for the next planning cycle (after 1985).
- A site-specific accuracy assessment was performed using land cover information derived from Landsat MSS data. The test was performed on the San Juan National Forest in southwestern Colorado using computer system that implements an iterative proportional fitting technique to normalize the coefficients within classification error matrices.
- The Video Image Communication and Retrieval (VICAR) System software was tested on the new NASA/JSC AS/3000 computer system to process Landsat data for supporting land management planning activities.
- A study was conducted to determine if remote access can be achieved in accessing data from the Agena facility in Houston to the Fort Collins Computer Center in Colorado.

The completion of the final phase of the Multiresource Inventory Methods Pilot Test is a vital step toward determining the extent to which Landsat and associated Geographic Information System technologies can facilitate, improve, or replace present multiresource inventory methods.

5.7.3 Change and Disturbance

New procedures for change detection, classification, and measurement of disturbances and changes in areas 3 acres or larger within National Forest boundaries were tested in 1981. Significant results and preliminary findings have been obtained from all of these activities.

Two studies were initiated to assess forest disturbances. One study evaluated the utility of incorporating high spatial resolution digital terrain data with MSS data to reduce the confusion between spectrally similar forest canopy conditions such as healthy forest and moderate defoliation. The results indicate that heavy defoliation is separable from either moderate defoliation or healthy forest but that these latter two conditions cannot be consistently separated. In the other study, a standardized, quantitative, ground-based technique was used to investigate the effects of forest canopy closure and other environmental variables on incoming solar radiation. Results indicate that the percentage of canopy closure is the single most important variable affecting incoming solar radiation.

In 1981, a new effort was begun on the development of modeling procedures to objectively estimate land suitability for a variety of uses. The focal point for the study is the San Juan National Forest in southwestern Colorado.

5.7.4 High-Altitude Sensors

Two high-resolution advanced panoramic camera systems previously integrated into the NASA U-2C aircraft were used successfully during 1981 to support RRI project activities. Two quantitative evaluations were made on products from the advanced panoramic camera.

A test was conducted to examine the potential utility of Landsat-D TM data for mapping forest resources relative to the present capabilities afforded by Landsat MSS data. The test results indicate that for specific type mapping purposes the simulated (TM) data showed a higher overall classification performance (60 percent for TM and 39 percent for MSS).

A simulation study was performed to develop procedures for analyzing TM data. The study sites were Pearl River Basin, Mississippi, Kershaw County, South Carolina, and Clearwater National Forest, Idaho. The results of this study indicate TM data can be successfully processed using NSTL/ERL software.

In addition, a SAR evaluation was conducted in 1981. The investigation was based on Seasat L-band and aircraft X-band SAR data. Preliminary results indicate that Seasat L-band SAR data improved classification by better delineating deciduous forest into several subclasses according to varying water regimes. Aircraft X-band SAR data have been acquired for the summer season; winter season data are scheduled for spring of 1982.

5.7.5 Habitat Mapping

Work being conducted to test the use and applicability of the vegetation component of the National Site Classification System was completed in 1981. Considerable work was done on habitat type mapping using remotely sensed data.

A test was conducted using a computerized spatial analysis system for evaluating wildlife habitat from vegetation cover maps. Cover maps were developed using Landsat MSS data. There is a tremendous need to further develop quantitative methods for evaluating wildlife habitat.

A study was conducted to evaluate procedures for habitat type mapping. This involved a digital data base consisting of a Landsat cover type map and a USDA/SCS soil survey map for the 7.5-minute quadrangle in Santa Cruz County, California. Results indicate there was essentially a split between soils classes in correlation with shrubs and forest vegetation.

This work has an important bearing on the integration of soils/vegetation relationships of different hierarchial categories.

5.8 CONSERVATION AND POLLUTION

5.8.1 Technical Objectives

The general objectives of the C/P project are to evaluate the usefulness of remote sensing technology to inventory and assess conservation practices, to aid in water resources management, and to monitor the effects of pollution on the environment.

Specific technical objectives of the FY 1981 program focused on:

- Evaluating selected remote sensors for their usefulness in the detection of conservation practices and integrating remotely sensed data with traditional data types into a geographic data base.

- Determining the suitability of present and planned remote sensing data for use in existing hydrologic models and developing new models or components to incorporate remotely sensed data for improved simulation accuracy.

- Using available visible, near-infrared, thermal-infrared, and microwave satellite data in conjunction with radiometric measurements from ground-based and aircraft systems to determine the effects of snow physical properties and changes in condition on spectral reflectance and passive and active microwaves.

- Studying the potential use of Landsat MSS data as input to water pollution models and evaluating methods of remotely measuring atmospheric oxidants in areas where impact on vegetation is suspected.

5.8.2 Detection of Conservation Practices

Soils and land use maps of the Goodwin Creek watershed were prepared. This watershed, located in northern Mississippi, is one of the field sites selected for studies and evaluations of conservation needs. These maps, plus information previously assembled on the location of specific conservation practices, will provide ground-truth data for the studies. The maps may also be used in evaluating remote sensing techniques for the identification and assessment of topographic, hydrologic, and ground-cover parameters used in hydrologic models. Digitizing these data for computer analysis is underway. Simulated TM data depicting summer full foliation have been acquired for the Idaho, Illinois, Kansas, Mississippi, and Oklahoma test sites.

5.8.3 Water Runoff Analysis

A study to determine the sensitivity of water runoff in storms of differing precipitation volume and duration to a variety of hydrologic variables has been started using Freeze's runoff model equations. The first variable tested was soil moisture, and it was found that runoff was extremely sensitive to the surface layer (upper 5 centimeters) soil moisture for certain rainfall events. Runoff sensitivity is greatest in shorter duration, lower rainfall volume events and less important as the storm length and volume increase. Figure 27 shows that of the storms tested runoff from the 3-hour storm (with 2 inches of rainfall) was most sensitive to accurate determinations of the soil moisture. If the soil moisture estimate for that storm (with a volumetric antecedent soil moisture of 0.28 centimeter/centimeter) was 10 percent in error, the resulting error in the runoff estimate would be 75 percent ($Q/Q_{0.28}$ = 1.75). These results indicate that there are many situations where accurate remote sensing estimates of soil moisture would be needed for accurate prediction of runoff.

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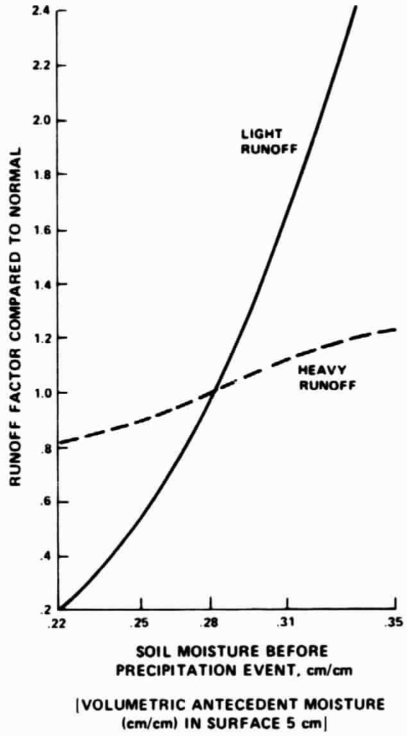

Figure 27.- Runoff sensitivity to errors in estimating surface soil moisture.

Procedures were developed and tested for using remotely sensed Landsat data in the estimation of the USDA/SCS runoff curve number. Determining land cover for this application using conventional methods is costly and tedious for large areas. Remote sensing offers a cost-effective alternative, as proven in a series of investigations. A manual of procedures was developed from this research and is being tested by the USDA/SCS. Training sessions for using the procedure have been held, and two test sites are currently being worked on (in Tennessee and Connecticut) with USDA/SCS personnel.

Seven hydrologic models, commonly used by water resources agencies, were examined to determine their compatibility with present and planned remote sensing capabilities. Hydrologic variables that can be addressed with remote sensing were identified: soil moisture, land cover, impervious area, snowcover extent, frozen ground extent, and snow water equivalent. The results indicate that remote sensing information has only limited value for use with the existing models in their present form. With minor modifications, however, the remote sensing usefulness in the models would be enhanced. The two most fruitful areas for modifications were indicated to be (1) adaptation of the National Weather Service snowmelt model to accept snow-covered area and (2) modification of the National Weather Service River Forecast System (NWSRFS) model to accept remote soil moisture measurements.

Since the mid-1970's, the Landsat series of satellites has acquired visible and near-infrared observations of the Earth at a frequency spatial resolution suitable for agricultural assessment purposes. More recently, satellite systems have acquired high-precision thermal-infrared data relating to surface thermal properties and moisture status. A data set from the Heat Capacity Mapping Mission illustrates the potential applications of such data for inferring evapotranspiration on a regional scale. An equation relating mean daily surface temperature to evapotranspiration rates yields results which are consistent with surface measurements of pan evaporation.

The snowmelt-runoff model is being tested on very large U.S. basins, probably the maximum sizes on which one would wish to apply the model. The initial results from tests on the Rio Grande Basin in Colorado (3419 square kilometers) and the Kings River in California (3999 square kilometers) indicate that, although these basins are about five to six times larger than the largest previously tested basins, the use of satellite snow cover in the model allows successful simulation of snowmelt runoff. The use of the model for forecasting snowmelt runoff will be tested in the Rio Grande Basin in FY 1982.

The distribution of soil moisture within two small watershed areas near Charlottesville, Virginia, is being studied. Soil moisture sampling has occurred on 10-meter and 1-meter grids within these areas. Geostatistical analysis procedures have been developed and perfected on a data set from Switzerland. The Virginia data will be analyzed with respect to the influence of soil moisture and its spatial distribution to the general hydrology of these areas.

Soil moisture observations have not been widely used on modeling because they are very difficult and costly to obtain. Thus, very little information is available with which to determine their value in water management and conservation. New remote sensing technology may change this situation. Studies have been conducted to show the potential value of soil moisture in infiltration modeling and runoff forecasting and thus support the continuation of the remote sensing research.

The hydrologic data for the Boise River Basin were updated. In addition, work commenced on the further development and adaptation of the continuous flow simulation (CFS) model to shorter time periods in order to assess its suitability for incorporation in a real-time forecast system. The NWSRFS extended streamflow prediction (ESP) model was obtained, and the source code was evaluated with respect to the feasibility of converting it to run on the PDP 11/34 minicomputer located at NASA/JSC. It was determined that, although the soil moisture and snow accumulation and ablation portions of the model could be converted to run on the minicomputer, a major reprogramming effort would be required to include all the desired features. The preferred way to use the model is through terminal access to the system on its host computer located in Suitland, Maryland.

5.8.4 Snowpack Studies

In order to measure remotely the snowpack properties important for agricultural water supplies and water management practices, microwave data and radiative transfer models have been used. As was shown previously, empirical and model results relating snow depth and microwave brightness temperature are very close. Nomograms based on model calculations are shown in figure 28. The model was used to predict the snow water equivalent using data

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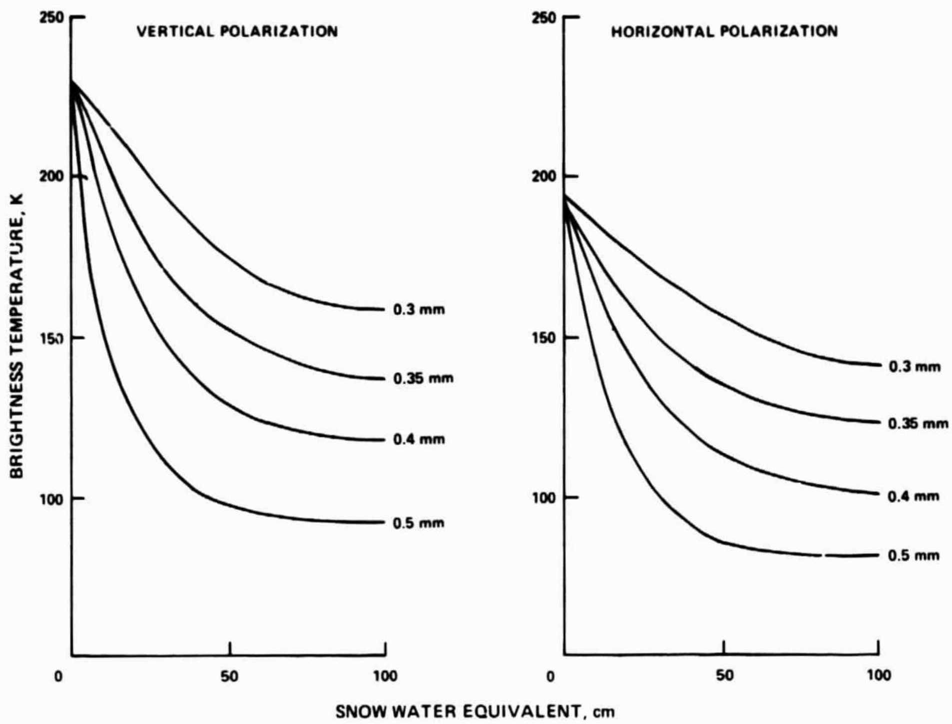

Figure 28.- Brightness temperature versus snow water equivalent for dry snow over unfrozen soil at various mean snow grain sizes. (Incidence angle equals 50°.)

collected in truck and aircraft experiments. As illustrated in table 4, the model predictions were close to the values measured in the field except in situations with a very deep snowpack, such as in Switzerland. It was found that the model mean snow grain size for the Switzerland data was unrepresentative; however, when it was changed to a more realistic value, the model predictions corresponded closely.

Reasonable agreement between in situ field measurements of snow reflectance and theoretical predictions of snow albedo was demonstrated in a qualitative sense, but quantitative agreement requires rationalization of individual measurement conditions. The results indicate the need for a better characterization of crystalline structure of snow and that current field methods of measuring liquid water content in snow may need to be improved.

Snow boundaries can usually be defined by the 37-gigahertz or 18-gigahertz data because of the sharp decrease in brightness temperature when going from land to snow. For dry snow, the 37-gigahertz data display a decrease in brightness temperature as a function of snow depth because of the stronger volume scattering effect of deeper snow. The onset of snowmelt is best defined by the microwave sensor because of the significant increase in the brightness temperature. The overall capability of microwave sensing of snow properties is shown best around 37 gigahertz.

TABLE 4.- COMPARISON OF MODEL PREDICTIONS[a] OF SNOW WATER EQUIVALENT USING TRUCK-MOUNTED EXPERIMENTAL DATA AT 37 GIGAHERTZ WITH GROUND-TRUTH MEASUREMENTS

Test site	Brightness temperature, K	Incidence angle, deg	Polarization	Snow water equivalent	
				Measured, cm	Predicted, cm
Truckee, California	233	45	Vertical	10	9
	210	45	Vertical	20	16
Steamboat Spring, Colorado	205	57	Horizontal	10	9
	188	57	Horizontal	20	15
Fraser, Colorado	210	50	Vertical	21	16
Davos, Switzerland	210	55	Vertical	50	[b]16

[a]One mean snow crystal radius of 0.35 mm was assumed for all data.

[b]A mean snow crystal radius of 0.25 mm produces a predicted snow water equivalent of ~50 cm.

Satellite-derived snow maps sometimes disagree with the traditionally prepared maps and thus can provide an improved portrayal of the spatial distribution of snow. Geostationary satellite images were found to be more useful than those from polar-orbiting satellites because of consistent geometric characteristics and greater frequency of coverage. Masking effects of forests severely impair the ability to interpret snow extent visually on most dates. Quantitative relationships were found between visible band brightness and snow depth in nonforested test sites ($r^2 < 0.86$). A digital snow-mapping technique was applied to forested test sites with fairly good success.

5.8.5 Pollution Assessment

During FY 1980, it was reported that initial sediment tests in the Langley Marine Unwelled Spectral Signature Laboratory (MUSSL) indicated that band 4 of the TM instrument appeared to have good potential for quantifying high sediment loads in reservoirs and rivers if appropriate atmospheric correction techniques could be developed. Initial MUSSL data indicated good signal discrimination for sediment concentrations between 80 and 783 milligrams per liter for wavelengths between 760 and 900 nanometers. During FY 1981, additional laboratory tests of sediments from Lake Chicot, Arkansas, and John H. Kerr Reservoir, Virginia, were conducted. These data confirm the FY 1980 laboratory results and suggest that concentrations as high as 1000 milligrams per liter may be discriminated with TM band 4. In addition, a study of historical Landsat data was completed for the Lake Chicot region. Those results indicate high reflectance in MSS band 7 (800 to 1100 nanometers) for high water turbidities which tend to confirm the laboratory results in a qualitative manner with actual flight data.

The FY 1981 MUSSL tests were used to evaluate several other factors in addition to the basic sediment spectral signature data discussed above. One factor

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was the definition of remote-sensing penetration depth and preferred water sample depth over a wide range of sediment concentrations. These data were first measured using sediments from Kerr Reservoir (fig. 29), and the accuracy of the measurements was confirmed during subsequent field experiments at the reservoir. The recommended depth for water sampling was taken from theoretical radiative transfer calculations and is the location at which 50 percent of the signal originates from below that point and 50 percent is caused by the water column above that depth. These data suggest a rule of thumb for waters with high sediment loads. For remote sensing experiments at visible wavelengths, water samples should be taken at a depth equal to 12 percent of the observed Secchi depth (the depth at which light is no longer visible from a standard, reflective target). It should be recognized that 90 percent of the signal originates in the layer above the remote sensing penetration depth, which is 50 to 75 percent of the Secchi depth. Subsequent MUSSL tests with Lake Chicot sediments confirmed these trends, which should be useful during future experiments conducted by USDA.

Another factor evaluated during MUSSL tests was the relation of quantum extinction coefficient, based on selective molecular absorption, to sediment concentration. The quantum extinction coefficient is one parameter that is input to theoretical reservoir water quality models. NASA was requested to perform measurements of this parameter using a USDA instrument as part of the Lake Chicot sediment tests. Good data were obtained (fig. 30), and the results were forwarded directly to the University of Minnesota for input to the water-quality model being developed under contract to USDA.

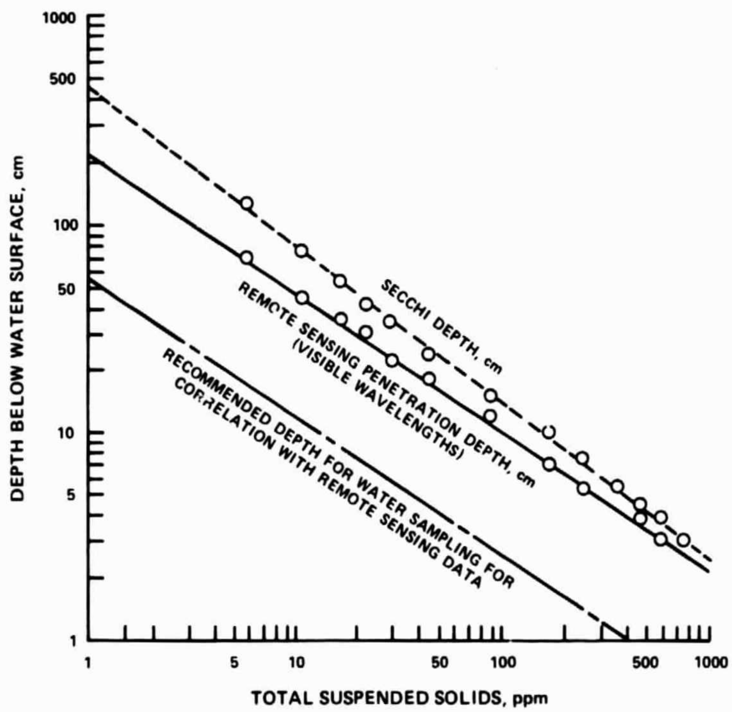

Figure 29.- Penetration depths at visible wavelengths from Kerr Reservoir sediment laboratory tests.

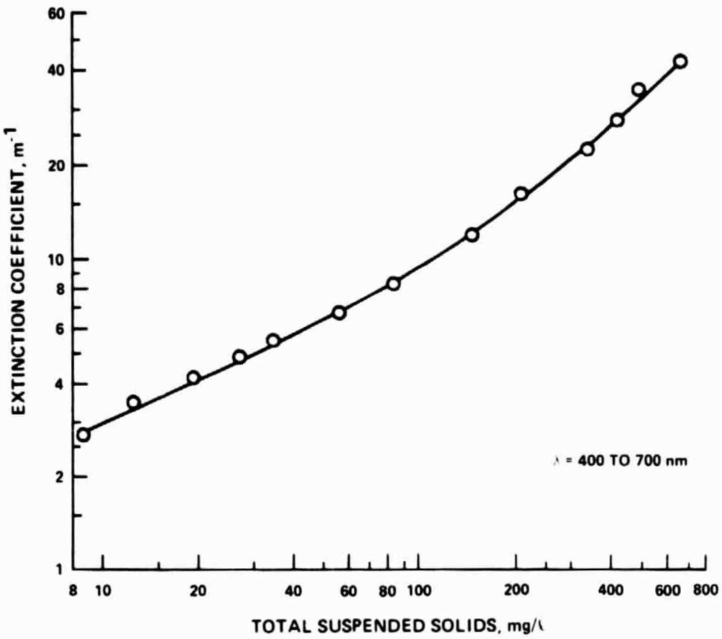

Figure 30.- Quantum extinction measurements from Chicot Lake sediment laboratory tests.

Six lakes are being investigated using Landsat data. These are upper and lower Lakes Chicot in Arkansas and Lakes Larto, Saline, and Turkey Creek in Louisiana. These lakes have been selected because there is an active restoration plan, either in the active stage or in the planning stage, for each of them which will correct a current problem. These restoration efforts should result in lake changes measurable by Landsat within the next few years.

During FY 1981, three field experiments were conducted at Kerr Reservoir. The first experiment (November 3 through 7, 1980) examined the relation of sediment concentration to underwater optics. Chlorophyll and dissolved organic carbon variations over the reservoir were found to confuse the relation between sediment concentration and visible wavelength beam attenuation coefficient (for sediment concentrations less than 21 milligrams per liter). From these data, it was concluded that underwater transmissometer measurements at near-infrared wavelengths would probably be the best optical approach for rapid measurement of sediment gradients in the water column. As a result, Virginia Polytechnic Institute and State University has procured a transmissometer modified to detect near-infrared transmission. The university is using this instrument to measure water column sediment gradients as part of its Kerr Reservoir modeling effort for AgRISTARS. Two additional field experiments were conducted at Kerr Reservoir during the periods November 19 and 20, 1980, and March 24 through 26, 1981. Both of these tests were Landsat experiments aimed at statistical quantification of sediment concentration to evaluate spatial resolution and adjacency effects. Remote-sensing penetration depth experiments were also conducted during the March test.

Permanent instrumentation has been purchased to monitor, record, and transmit via GOES water-quality data obtained in the principal inflow and outflow of Lake Chicot. This equipment will be assembled and installed during November 1981. The water-quality variables monitored were selected on the basis of their pertinence to the problem in Lake Chicot and the availability of equipment which will stand up and maintain calibration in the field for long periods of time. These variables are stage, turbidity, dissolved solids, and temperature. These variables have been correlated to many other of the water-quality variables of interest through an extensive study of the lake.

5.8.6 Air Pollution

A spectroradiometer was used to measure reflectance spectra (425 to 1550 nanometers) from plants that received a single acute dose of ozone (2 hours at 0.6 ppm). The plants were grown and exposed under controlled conditions so that results of different exposures would be as uniform as possible. A comparison of the measured snap bean spectra with field and laboratory spectroradiometer measurements of sulfur-dioxide-injured soybeans and winter wheat indicates a similar response. Both sets of data show an increase of reflectance in the green (500 to 550 nanometer) and red (650 to 700 nanometer) spectral regions and a decrease in the near-infrared (700 to 790 nanometer) region to red reflectance ratio. Published spectra of ozone-injured cantaloupe plants made with a laboratory spectrophotometer (especially equipped for reflectance measurements) showed similar significant reflectance increases in the red, green, and near-infrared (700 to 2500 nanometer) regions. However, the magnitude of these ozone-induced differences decreased when plants were scanned in a field setting. Although these comparisons are qualitative and not statistical, they indicate that the snap bean spectra are representative of injury induced by pollutants, particularly ozone, and should serve as a good test species.

APPENDIX A

AgRISTARS MANAGEMENT AND ORGANIZATION

1. INTRODUCTION

The program scope of AgRISTARS specifically addresses the seven information requirements identified by the Secretary of Agriculture.[3] It is structured into projects designed to conduct research, develop, test, and evaluate the various applications of aerospace technology. These projects are designed to support a decision regarding the routine use of remote sensing technology by USDA.

2. RESPONSIBILITIES

The organization and management philosophy recognizes that each involved Government agency enters into an agreement to support remote sensing research which will address the information requirements defined by the USDA. Each Government agency budgets, manages, and maintains control of the resources necessary to meet its own responsibilities as jointly agreed upon (see fig. A-1).

3. JOINT MANAGEMENT STRUCTURE/ORGANIZATION

The program utilizes the matrix management system. There are eight major projects, each having a number of tasks assigned to various line organizations of the participating agencies. Each of the eight projects has a project manager who reports to a Program Management Team (PMT). The PMT, in turn, takes its direction and guidance from the Interagency Coordinating Committee (ICC). As viewed in figure A-2, the functional relationships are structured into a three-level management system, each having distinct responsibilities.

3.1 INTERAGENCY POLICY BOARD

The Interagency Policy Board (IPB), chaired by USDA, is a joint agency group of policy-level officials at the Assistant Secretary or equivalent level. It is responsible for approving major interagency agreements and establishing basic policies and guidelines for the program.

3.2 INTERAGENCY COORDINATING COMMITTEE (LEVEL 1)

The ICC is comprised of membership from USDA, NASA, USDC, USDI, and AID. It is chaired by the USDA and is responsible for: approving AgRISTARS program objectives and establishing priorities; approving the AgRISTARS Program Plan; assessing progress, identifying problems, and developing corrective actions; and coordinating the use of resources assigned to the program.

3.3 PROGRAM MANAGEMENT TEAM (LEVEL 2)

The PMT represents a joint approach to management which provides participation, project integration, and needed visibility by all participants and assures full responsiveness to USDA information requirements.

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[3] Joint Program of Research and Development of Uses of Aerospace Technology for Agricultural Programs, February 1978.

USDA

- DEFINITION OF USDA INFORMATION REQUIREMENTS.
- YIELD MODEL RESEARCH, DEVELOPMENT, AND TESTING (RD&T) AND APPLICATIONS.
- RD&T – APPLICATIONS ANALYSIS FOR AREA, YIELD, AND PRODUCTION ESTIMATION.
- DEVELOPMENT OF AGRONOMIC/ANCILLARY DATA BASE.
- USER EVALUATION.
- GROUND DATA COLLECTION.
- RD&T AND APPLICATIONS FOR CROP WEATHER ASSESSMENTS.[1]
- RD&T AND APPLICATIONS FOR EW/CCA ANALYSIS.
- RD&T AND APPLICATIONS FOR RRI ANALYSIS.
- RD&T AND APPLICATIONS FOR LAND USE, PRODUCTIVITY AND C/P ANALYSIS.
- RD&T FOR SOIL MOISTURE MEASURING TECHNIQUES.
- LARGE-SCALE APPLICATIONS TESTS.

NASA

- RD&T FOR FOREIGN CROP AREA ESTIMATION.
- RD&T FOR COMBINING AREA AND YIELD ESTIMATES FOR FOREIGN CROP PRODUCTION.
- FIELD RESEARCH.
- LANDSAT DATA ACQUISITION.
- RD&T – SPECTRAL INPUTS TO YIELD MODELS.
- RD&T – SPECTRAL INPUTS TO QUANTITATIVE EW/CCA.
- RD&T FOR SPECTRAL ANALYSIS RELATED TO INVENTORY AND CONDITION ASSESSMENT TECHNIQUES FOR RRI.
- RD&T INVENTORY AND MONITORING TECHNIQUES FOR LAND USE AND C/P.
- RD&T FOR REMOTELY SENSED SOIL MOISTURE MEASURING TECHNIQUES.
- DEFINITION OF REQUIREMENTS FOR FUTURE SENSORS (INCLUDING IN-SITU).

USDC

- METEOROLOGICAL DATA BASE.
- RD&T AND APPLICATIONS OF ENVIRONMENTAL SATELLITE DATA.
- RD&T METEOROLOGICAL YIELD MODELS.
- RD&T WEATHER/CROP ASSESSMENTS.[2]
- RD&T ON USE OF CONVENTIONAL AND SATELLITE-DERIVED METEOROLOGICAL DATA APPLIED TO RRI AND C/P.
- RD&T ON TECHNIQUES FOR DETERMINING SOIL MOISTURE.

USDI

- LANDSAT DATA STORAGE, RETRIEVAL, AND DISSEMINATION.

AID

- EVALUATION OF UTILITY OF RD&T RESULTS FOR APPLICATIONS IN DEVELOPING COUNTRIES.

[1]Primary emphasis is on assessment of crop conditions (e.g., yield, production) using meteorological data as an input to develop needed information.

[2]Primary emphasis is on acquisition and evaluation of meteorological data in terms of its utility for crop condition assessment.

Figure A-1.- AgRISTARS responsibilities of five Government agencies.

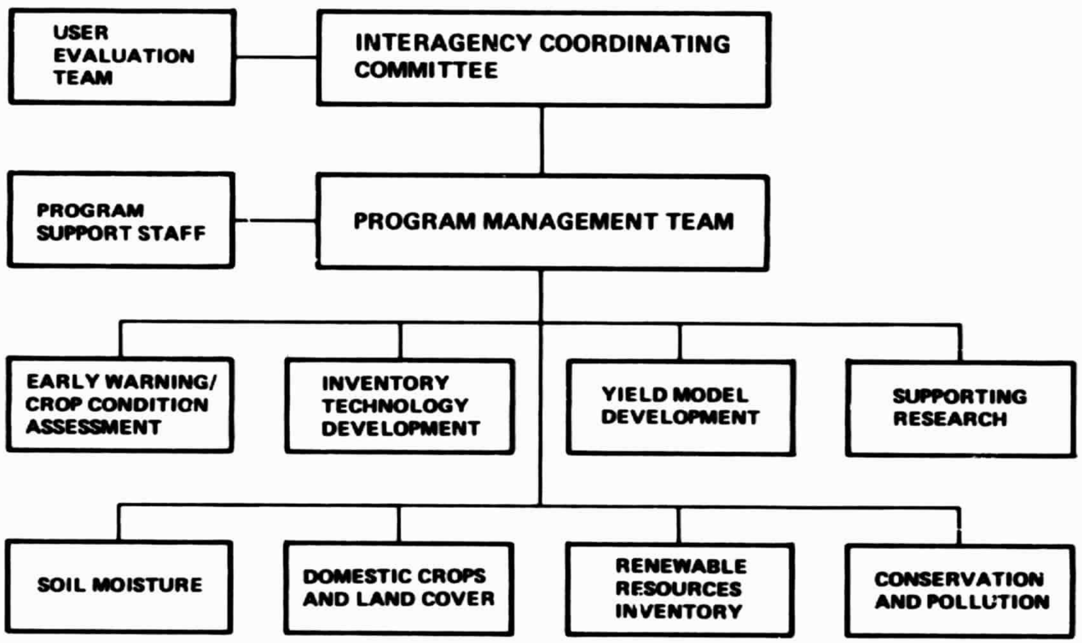

Figure A-2.- Joint agency program management and functional relationships.

The PMT acts as the project change authority for all issues and significant changes affecting specified control milestones and schedules and project goals and objectives.

3.4 PROGRAM SUPPORT STAFF

The Program Support Staff (PSS) is led by USDA, has membership from all agencies, and provides staff support to the PMT.

4. PROJECT MANAGERS (LEVEL 3)

Each of the projects is headed by a project manager who was selected from a participating agency, based principally upon considerations of technical expertise and expected levels of agency involvement. The project managers are responsible to the PMT for planning and managing activities within their projects. This includes defining project content, identifying expected products and schedules, assessing status and progress, identifying problems, making change recommendations, planning and defining tasks, and participating with other project managers in the integration of the various projects.

5. REVIEW AND REPORTING

A review and reporting plan has been established to support major program planning and budgetary events.

Each year in the May-June time period, the PMT, project managers, and task managers update each of the project implementation plans to reflect current budgets and the results and recommendations resulting from the various technical reviews.

Internal reviews are held at the various levels of management as required.

6. DOCUMENTATION

All aspects of the program are being documented in full by: reports; technical memoranda and journal articles, as appropriate; press releases; and program progress reports.

7. PARTICIPATING ORGANIZATIONS

Many elements of Government, industry, and the university community are participants in AgRISTARS. These organizations are shown in figure A-3.

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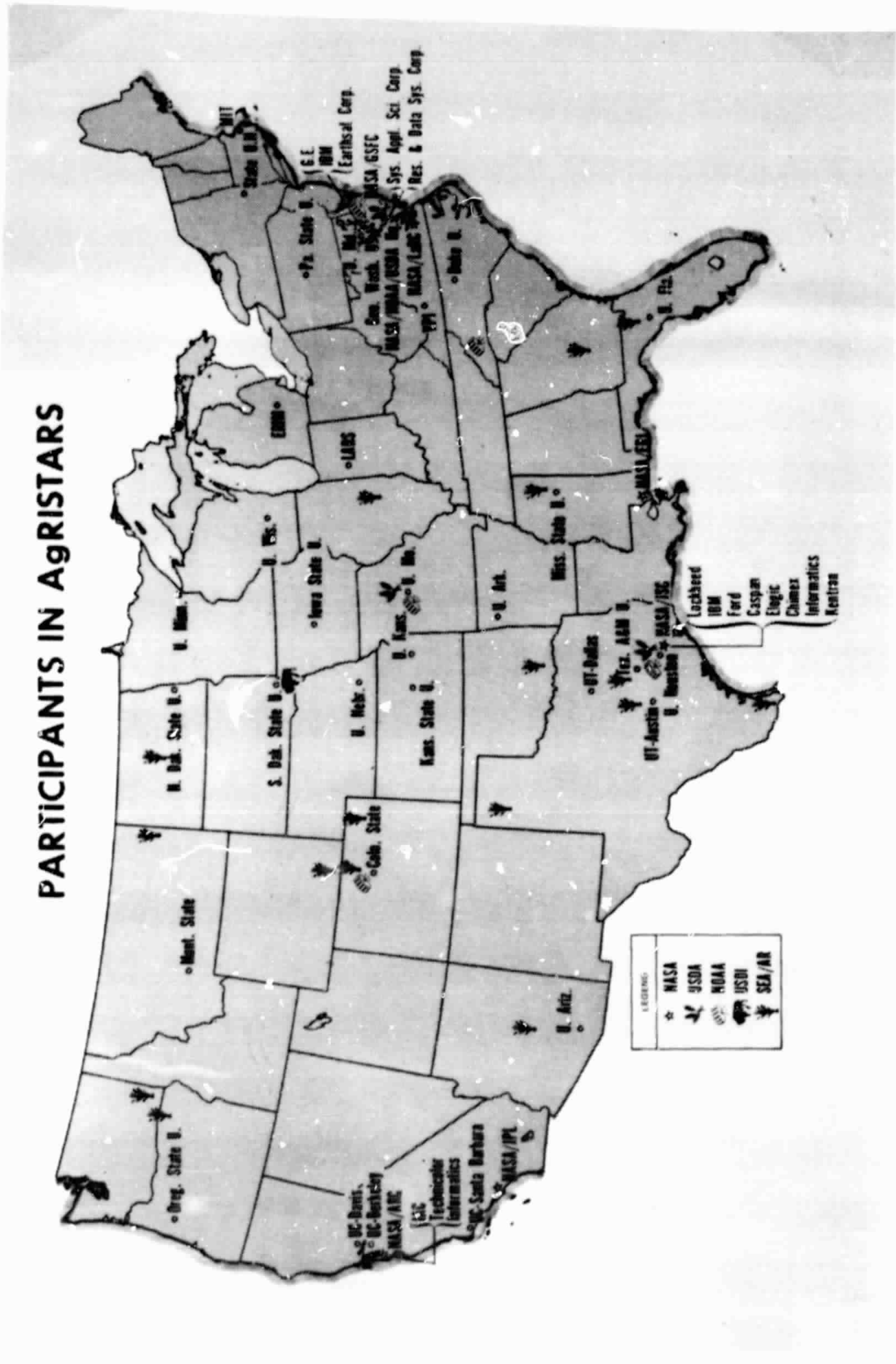

Figure A-3.- Organizations participating in AgRISTARS.

APPENDIX B

AgRISTARS PROGRAM AND PROGRAM-RELATED DOCUMENTATION

1. GENERAL

This appendix contains a by-project listing of all AgRISTARS program and program-related documentation from program inception through documentation of tasks completed in FY 1981. The listing provided has been further subdivided within each project into areas of plans, reports, procedures, etc., to facilitate easy retrieval of desired documentation.

2. REQUESTING DOCUMENTS

2.1 CONTROLLED DOCUMENTS

Documents which carry an AgRISTARS control number may be obtained from NASA/JSC by either telephone or mail request. Address requests to:

Lyndon B. Johnson Space Center
SK - Documentation Manager
Houston, Texas 77058
Telephone 713-483-4776

2.2 UNNUMBERED DOCUMENTS (00900 SERIES AND PRESENTATIONS)

Requests for material within this area will be honored based upon availability of data. Requests should be made to:

Lyndon B. Johnson Space Center
(Appropriate Project)
SK - Program Support Staff
Houston, Texas 77058
Telephone 713-483-2548

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EW/CCA Instructions - 00100

1-01. Soil Moisture/Early Warning and Crop Condition Assessment Interface Control Document. MU-J0-00101, JSC-16842, Nov. 1980.

1-02. Yield Model Development/Early Warning and Crop Condition Assessment Interface Control Document. MU-J0-00102, JSC-16843, Nov. 1980.

EW/CCA Reports - 00400

1-03. Meteorological Satellite Data - A Tool to Describe the Health of the World's Agriculture. EW-N1-04042, JSC-17112, Feb. 1981.

1-04. Hand-Held Radiometry - A Set of Notes Developed for Use at the Workshop on Hand-Held Radiometry. EW-U1-04052, JSC-17118, Oct. 1980.

1-05. Soil Moisture Inferences From Thermal Infrared Measurements of Vegetation Temperatures. EW-U1-04068, JSC-17125, Mar. 1981.

1-06. Large Area Application of a Corn Hazard Model. EW-U1-04074, JSC-17130, Mar. 1981.

1-07. The Characteristics of TIROS, GOES, DMSP, and Landsat Systems. EW-N1-04075, JSC-17131, Mar. 1981.

1-08. The Environmental Vegetative Index - A Tool Potentially Useful for Arid Land Management. EW-N1-04076, JSC-17132, Mar. 1981.

1-09. Canopy Temperature as a Crop Water Stress Indicator. EW-U1-04077, JSC-17133, Mar. 1981.

1-10. Registration Verification of SEA/AR Fields. EW-L1-04101, JSC-17251, LEMSCO-16204, May 1981.

1-11. Plant Cover, Soil Temperature, Freeze, Water Stress, and Evapotranspiration Conditions. EW-U1-04103, JSC-17143, Mar. 1981.

1-12. Utilization of Meteorological Satellite Imagery for Worldwide Environmental Monitoring: The Lower Mississippi River Flood of 1979. EW-N1-04104, JSC-17144, Mar. 1981.

1-13. Techniques in the Use of NOAA 6-n Data for Crop Condition Evaluation. EW-N1-04105, JSC-17145, Apr. 1981.

1-14. Two Layer Soil Water Budget Model - A Tool for Large Area Soil Moisture Estimates. EW-U1-04106, JSC-17146, Apr. 1981.

1-15. Comparison of Landsat-2 and Field Spectrometer Reflectance Signatures of South Texas Rangeland Plant Communities. EW-U1-04107, JSC-17147, Apr. 1981.

1-16. Environmental Factors During Seed Development and Their Influence on Pre-Harvest Sprouting in Wheat. EW-U1-04115, JSC-17157, May 1981.

1-17. A Meteorological Driven Maize Stress Indicator Model. EW-U1-04119, JSC-17399, July 1981.

1-18. Review of Literature Relating to the Modeling of Soil Temperature Based on Meteorological Factors. EW-21-04124, NAS-916007, July 1981.

1-19. Airborne Observed Solar Elevation and Row Direction Effects on the Near-IR/Red Ratio of Cotton. EW-U1-04144, JSC-17420, Aug. 1981.

1-20. Agricultural Research Service Research Highlights in Remote Sensing for Calendar Year 1980. EW-R1-04147, July 1981.

EW/CCA Plans - 00600

1-21. Early Warning/Crop Condition Assessment Implementation Plan. EW-J0-C0617, JSC-16852, 1980.

1-22. Early Warning/Crop Condition Assessment Implementation Plan. EW-J1-C0622, JSC-16862, 1981.

EW/CCA Procedures - 00700

1-23. Program Development and Maintenance Standards. EW-U0-00700, JSC-16367, June 1980.

1-24. Limited Area Coverage/High Resolution Picture Transmission, LAC/HRPT Tape Conversion Processor User's Manual. EW-L0-00701, JSC-16373, LEMSCO-15325, Sept. 1980.

1-25. Limited Area Coverage/High Resolution Picture Transmission (LAC/HRPT) Tape IJ Grid Pixel Extraction Processor User's Manual. EW-L0-00702, JSC-16374, LEMSCO-15326, Sept. 1980.

1-26. Limited Area Coverage/High Resolution Picture Transmission (LAC/HRPT) Data Vegetative Index Calculation Processor User's Manual. EW-L0-00703, JSC-16375, LEMSCO-15327, Sept. 1980.

1-27. Tape Merge/Copy Processor. EW-L0-00704, JSC-16381, LEMSCO-15356, Sept. 1980.

1-28. EROS to Universal Tape Conversion Processor. EW-L0-00705, JSC-16382, LEMSCO-15357, Sept. 1980.

1-29. Conversion of SPU-Universal Disk File to JSC-Universal Tape Storage - CONVRT User's Guide. EW-L0-00706, JSC-16821, LEMSCO-15608, Sept. 1980.

1-30. Patch Image Processor User's Manual. EW-L0-00707, JSC-16833, LEMSCO-15692, Sept. 1980.

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1-33. Wheat Stress Indicator Model, Crop Condition Assessment Division (CCAD) Data Base Interface Driver, User's Manual. EW-L1-00711, JSC-17114, LEMSCO-16034, Feb. 1981.

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1-35. General Graphing System (GRAPH) User Guide. EW-L1-00716, JSC-17397, LEMSCO-16667, June 1981.

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